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THE CALCULATION OF MILLIMETER AND SUBMILLIMETER WAVE ABSORPTION LINE PARAMETERS FOR THE MOLECULAR OXYGEN ISOTOPES: (16)O2, (16)O(18)O, AND (18)O2

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Riverside Research Institute

Prepared for:

Army Missile Command
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TECHNICAL REPORT T-1/306-3-14

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program (described elsewhere) which calculates the attenuation vs. altitude at any fixed frequency in the millimeter-to-submillimeter wave region.

The calculations were performed on the XDS Sigma 9 computer at RRI by means of APL programs which are listed and explained in the report. Several sets of published molecular constants were used to obtain an estimate of the degree of reliability of the resulting line parameters. Appendices include the predicted transition frequencies, transition moments, and lower state energies for each set of molecular constants employed; tabulations of rotational state sums vs. temperature; line parameters for each of the three isotopes studied, separately; and a list of the 318 absorption lines below 300 cm^{-1} whose strengths exceed 3.7 E-30 cm^{-1} per molecule cm^{-2} at 296K.

AUTHORIZATION

This report describes work performed at Riverside Research Institute by M. Greenebaum with the assistance of D. Koppel and S. Rosenberg. The report was written by M. Greenebaum.

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ABSTRACT

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Introduction

This Technical Report describes a portion of the calculations performed at RRI on the atmospheric propagation characteristics of electromagnetic radiation of millimeter and submillimeter wavelengths. The calculations described here are those of a set of absorption line parameters for three isotopes of molecular oxygen: $^{16}O_2$, $^{16}O^{18}O$, and $^{18}O_2$. These line parameters are required by the SLAM program (described in a separate Tech. Report) to calculate the attenuation *vs*. altitude at any fixed frequency in the covered wavelength region. The line parameters are: frequency (cm^{-1}), strength at 296K (cm^{-1} per molecule per cm^2), linewidth (cm^{-1} per atm), and lower state energy (cm^{-1}) for each transition, labelled by the appropriate quantum numbers, date of calculation (month, year), isotope, and species (7 for oxygen). The calculations were done on the basis of several sets of published molecular constants[1-7] by means of APL programs written for the XDS Sigma 9 computer at RRI. The programs are listed and explained in this report.

The succeeding sections of this report discuss the molecular theory of the oxygen molecule, the calculation of line positions, lower state energies, and integrated line strengths, evaluation of line widths, and the format of the line parameters listed in the Appendices. In addition to the line parameter listings (for all isotopes except $^{16}O^{17}O$), the Appendices contain the following:

a brief summary of APL notational conventions, predictions of transition frequencies and lower state energies to 9-digit accuracy (both in GHz and in cm^{-1}) for each set of molecular parameters employed, a tabulation of rotational state sums *vs.* temperature, and several other listings of general interest, but not required in the body of the report.

Molecular Theory of the Oxygen Isotopes

The first essentially correct theoretical treatment of the fine structure of the molecular oxygen ground state was that of Tinkham and Strandberg.[1] This theory (applicable to $^{16}O_2$ and $^{18}O_2$) predicted that, in addition to the well-known microwave spectrum, oxygen also possessed a "forbidden" submillimeter spectrum, and made predictions of the line strengths. The essential correctness of the theory (with the exception of the strength prediction for one type of "forbidden" transition) was shown by Gebbie, et al.,[8] on the basis of laboratory measurements at low resolution, as well as by the observation of atmospheric absorption at high altitudes using the Sun as a source.[9,10] In his recent thesis, Steinbach has succeeded in clarifying the theory with the aid of the transformation theory for spherical tensor operators,[11] and it is based on Steinbach's formulation that the RRI calculations of line strengths have been performed, especially since it places $^{16}O^{18}O$ on an equal footing with the homonuclear isotopes.[7,11]

The basic physical features are as follows: None of the oxygen molecular isotopes possess a permanent electric dipole moment. For the $^{16}O_2$ and $^{18}O_2$ isotopes, this follows from the homonuclear symmetry, whereas for $^{16}O^{18}O$ (as well as $^{16}O^{17}O$), this is an experimental fact.[11] The electronic ground state being $^3\Sigma_g^-$, the average (electronic) orbital angular momentum vanishes ($\Lambda = 0$)--although there is an instantaneous non-zero value of the orbital angular momentum which produces a precessing magnetic dipole moment of orbital origin. Since the electronic

ground state is a triplet state, the total electronic spin is $S = 1$, so that molecular oxygen has a permanent magnetic dipole moment of approximately two Bohr magnetons.[1] The oxygen molecule interacts via this dipole moment with the magnetic field associated with an electromagnetic wave. It has been noted by several authors[1,11,12] that oxygen is capable of very strong atmospheric absorption of electromagnetic radiation despite the weakness of magnetic dipole transitions relative to electric dipole transitions (by two or more orders of magnitude, in general) by virtue of its abundance (21% by volume of air at "all" altitudes). (By way of contrast, water, with the large electric dipole moment of 1.9 Debye units, decreases rapidly in concentration with altitude above 3 km.)

As is typical for microwave and submillimeter wave absorption, the molecular oxygen absorption frequencies in this region are associated with changes in the rotational energy of the molecule, with no change taking place either of the vibrational or of the electronic state. (At room temperature, both the ground vibrational state and the first excited vibrational state are significantly populated and are taken into account in these calculations.) The energy in any given rotational state is the sum of three terms: the pure-rotation term, $H_{rot} = B\vec{N}^2$ (where $\vec{N}$ is the rotational angular momentum operator describing end-over-end rotations of the molecule, and B is the rotational parameter--itself a function of N when "stretching", i. e., rotation-vibration interaction, is taken into account); a spin-rotation (or spin-orbit[1]) term, $H_{s-r} = \mu\vec{N}\cdot\vec{S}$ (where $\vec{S}$ is the total electron spin operator, and μ is the spin-rotation coupling parameter--likewise N-dependent under centrifugal stretching); and a spin-spin term, $H_{s-s} = (2/3)\lambda(3S_z{}^2-\vec{S}^2)$ (where S_z is the body-fixed component of $\vec{S}$ along the internuclear axis of the molecule, and λ is the spin-spin interaction parameter, comparable in magnitude to B). A spectroscopic convention is followed here: not only frequencies, but also energies and rotational,

spin-rotation and spin-spin interaction parameters, are expressed in frequency units: GHz or cm^{-1}. Note that the speed of light is 29.9792458(1.2) GHz per cm^{-1},[13] so that 1 $cm^{-1} \approx$ 30 GHz.

Since the nuclear spins of ^{16}O and of ^{18}O are zero (I = 0), no hyperfine energy term appears in the Hamiltonian. For ^{17}O, however, I = 5/2, enormously complicating the spectrum of $^{16}O^{17}O$ relative to that of $^{16}O^{18}O$, $^{16}O_2$, or $^{18}O_2$.[14-16] The hyperfine spectrum of $^{16}O^{17}O$ (as well as the Zeeman effect in the presence of a d-c magnetic field, for all isotopes[11]) will be treated in another Technical Report,[17] based on some results by Steinbach.[16] The relative abundances of the various isotopic species of molecular oxygen are given in Table I.

Therefore, restricting our attention to oxygen molecules with I = 0, there are only three angular momentum operators to consider: $\vec{N}$, the rotational angular momentum, $\vec{S}$, the spin angular momentum, and $\vec{J} = \vec{N} + \vec{S}$, the total angular momentum. $\vec{J}$ enters because the spin-rotation term may be rewritten as a function of $\vec{N}^2$, $\vec{S}^2$, and $\vec{J}^2$ alone, since $\vec{N}\cdot\vec{S} = (1/2)(\vec{N}^2+\vec{S}^2-\vec{J}^2)$. As is well-known,[1,8,12,18] the ordinary microwave absorption spectrum of $^{16}O_2$ can be explained to a good first approximation by assuming the spin tightly coupled to the rotation in a pure Hund's case (b) fashion. However, such a coupling scheme fails to predict the existence of the submillimeter absorption lines and also fails to reproduce all the details of the observed microwave spectrum.[1,19] Consequently, Tinkham and Strandberg performed the energy calculations in a Hund's case (a) basis (in which J, N, S, and M_S are good quantum numbers) and transformed to a Hund's case (b) basis (in which J, M_J, N, and S are good quantum numbers).[1] The calculations are fairly involved, and the expressions needed to calculate transition strengths contain typographical errors, but (with the exception noted by Gebbie et al,[8] and independently by Steinbach[11]) their numerical values for the transition matrix elements (line strengths)

Table I: Relative Abundances of the Isotopes of O_2

Isotopic Species	Relative Abundance[a]
$^{16}O^{16}O$	0.99519
$^{16}O^{18}O$	$4.07 \cdot 10^{-3}$
$^{16}O^{17}O$	$7.38 \cdot 10^{-4}$
$^{18}O^{18}O$	$4.16 \cdot 10^{-6}$
$^{17}O^{18}O$	$1.51 \cdot 10^{-6}$
$^{17}O^{17}O$	$1.37 \cdot 10^{-7}$

---

[a] Based upon the following isotopic abundances of atomic oxygen: ^{16}O: 99.759%, ^{17}O: 0.037%, ^{18}O: 0.204%

Reference: Handbook of Chemistry and Physics, 52nd Edition, 1971-1972, Chemical Rubber Co., Cleveland, Ohio.

agree with those of later workers.[11] A different approach has been taken by Steinbach[7,11] based on earlier (but incorrect[1,3]) calculations by Hill and Mizushima.[19] In this approach, all calculations are carried out in a Hund's case (b) basis, and one finds the matrix elements of S_z in this basis. Steinbach[11] performed the calculations by using the theory of irreducible tensor operators as summarized by Cook and DeLucia[12] to obtain explicit algebraic expressions for the eigenvectors describing the stationary energy states:

$$|\psi\rangle = \alpha|J,M_J,N=J-1,S\rangle + \beta|J,M_J,N=J,S\rangle + \gamma|J,M_J,N=J+1,S\rangle \,, \qquad \ldots(1)$$

in terms of the three parameters, α, β, and γ, using the Wigner 6-j symbols. The fact that (with one exception) either α or γ is nearly 1 while the other is almost (but not quite) zero[11] means that oxygen is "almost" Hund's case (b), but that N has ceased to be a "good quantum number" except for "diagonal" states (corresponding to $\alpha_0 = \gamma_0 = 0$, $\beta_0 = 1$ in Steinbach's notation[11]), as noted earlier by Mizushima and colleagues[3,4,6,19] and by Tinkham and Strandberg.[1] In these calculations, the molecular rotational, spin-spin, and spin-rotation parameters, B, λ, and μ, are assumed to depend as follows on N and J:[3,6,11,19]

$$\left.\begin{aligned} B &= B_0 + B_1 N(N+1) + B_2 N^2(N+1)^2 + \cdots \\ \lambda &= \lambda_0 + \lambda_1 N(N+1) + \cdots \\ \mu &= \mu_0 + \mu_1 N(N+1) + \cdots \end{aligned}\right] \text{for } N = N' \text{ matrix elements,}$$

$$\lambda = \lambda_0 + \lambda_1(J^2+J+1) + \cdots \qquad \text{for } N \neq N',\ N = J\underline{+}1 \text{ matrix elements.} \qquad \ldots(2)$$

The seven parameters, B_0, B_1, B_2, λ_0, λ_1, μ_0, and μ_1 are obtained by fitting observed transition frequencies to the model Hamiltonian,[1-7] supplemented by calculations of the isotopic

dependence[18] of these parameters, where required.[7,11,21] The separation between the lowest rotational levels in the ground vibrational state (v = 0) and in the first excited vibrational state (v = 1), denoted by $\Delta G_{1/2}$ by Herzberg,[18,21] is taken to be 1556.378(7) cm^{-1}, based upon the re-evaluation by Albritton, et al[5] of electron optical[21] and microwave[3,4] data.

These parameters, as given by Refs. 1 through 7, have been inserted into APL "functions" (programs) such as PARAMSTEIN, listed in Fig. 1. A brief description of the APL programming language is contained in Appendix A. In Appendix B, the parameters are explicitly given, together with the transition matrix elements, transition frequencies, etc., calculated from them as discussed in the ensuing sections. Listings of two similar APL parameter-setting programs used in the RRI calculations, PARAMSTEINUPPER and PARAMETERS, are given in Appendix C.

The parameters quoted for Tinkham and Strandberg[1] are based on the correspondences: $B_{(0)T-S} = B_0$, $4\epsilon^2 B_{(0)T-S} = B_1$, $B_2 = 0$, $\lambda_{(0)T-S} = \lambda_0$, $4\epsilon^2\lambda_{1\,T-S} = \lambda_1$, $\mu_{0\ T-S} = \mu_0$, $\mu_1 = 0$. (See Ref. 1, footnote 41.) The parameters quoted for Albritton, et al[5] are based on electronic optical data[21] for v = 0, and on ground-state microwave data[3,4] and upper-state electronic optical data[21] for v = 1. (See Ref. 5, p. 116, Table IX.)

Line Positions and Lower State Energies

Except for an arbitrary additive constant, the eigenvalues of the Hamiltonian operator in the stationary states $|\psi_i\rangle$ are the allowed energy levels. (Different authors[1,3,5] choose different additive constants.) We follow the calculational scheme of Mizushima, et al,[3,4,6] and Steinbach and Gordy[7,11] in which the eigenvalues are obtained by solving the secular determinantal equations:

$$|H_{11} - E| = 0,\ H_{11} = \langle J{=}0, M_J, N{=}1, S \,|\, H \,|\, 0, M_J, 1, S \rangle, \quad \ldots(3a)$$

```
    ∇ PARAMSTEIN;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1
      ⍝ 'REFNO' IS 7, CORRESPONDING TO W. STEINBACH AND W. GORDY, PHYS.
      ⍝ REV. A, VOL. 11, NO. 3, PP. 729 TO 731, MARCH 1975.
      VECB0←43.10046 40.707408 38.31373
      VECB1←¯0.00014501 ¯0.000129 ¯0.000115
      VECB2←0 0 0
      VECLAM0←59.501341 59.499097 59.496698
      VECLAM1←5.848E¯5 5.312E¯5 5.211E¯5
      VECMU0←¯0.252586 ¯0.238488 ¯0.224439
      VECMU1←¯2.47E¯7 ¯6.19E¯7 ¯3.51E¯7
      REFNO←7
      ISO←66 68 88
      ISOTEXT←3 7⍴' '
      ISOTEXT[1;]←'O16=O16';ISOTEXT[2;]←'O16=O18';ISOTEXT[3;]←'O18=O18'
      INPUT:'PLEASE TYPE ISOTOPE CODE: 66, 68, OR 88'
      X←ISO⍳⎕
      →(X>⍴ISO)/INPUT
      B0←VECB0[X]
      B1←VECB1[X]
      B2←VECB2[X]
      LAM0←VECLAM0[X]
      LAM1←VECLAM1[X]
      MU0←VECMU0[X]
      MU1←VECMU1[X]
      '

THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR ';ISOTEXT[X;];':

'
      'B0 = ';B0;' GHZ;   '
      'B1 = ';B1;' GHZ;   '
      'B2 = ';B2;' GHZ;
      '
      'LAM0 = ';LAM0;' GHZ;    '
      'LAM1 = ';LAM1;' GHZ;
      '
      'MU0 = ';MU0;' GHZ;    '
      'MU1 = ';MU1;' GHZ.
      '
      TEMP←296
      'TEMP = ';TEMP;'    REFNO = ';REFNO;'    ISOTOPE = ';ISO[X]
      NINPUT←¯1+2×(⍳27)
      →(X≠2)/0
      NINPUT←¯1+⍳40
    ∇
```

Fig. 1: Listing of APL function PARAMSTEIN

$$\begin{vmatrix} a-E & 0 & d \\ 0 & b-E & 0 \\ d & 0 & c-E \end{vmatrix} = 0, \text{ where } J \neq 0, \text{ and,} \qquad \ldots(3b)$$

under the simplifying assumption[4-7,11] that $B_2 = 0$,

$$a = \langle J, M_J, N{=}J-1, S \mid H \mid J, M_J, N{=}J-1, S \rangle$$

$$= B_0 J(J-1) + B_1 J^2(J-1)^2 + \mu_0(J-1) + \mu_1 J(J-1)^2$$

$$+ [(2/3) - 2J/(2J+1)] \, [\lambda_0 + \lambda_1 J(J-1)] ,$$

$$b = \langle J, M_J, N{=}J, S \mid H \mid J, M_J, N{=}J, S \rangle$$

$$= B_0 J(J+1) + B_1 J^2(J+1)^2 - \mu_0 - \mu_1 J(J+1)$$

$$+ (2/3) \, [\lambda_0 + \lambda_1 J(J+1)] ,$$

$$c = \langle J, M_J, N{=}J+1, S \mid H \mid J, M_J, N{=}J+1, S \rangle$$

$$= B_0(J+1)(J+2) + B_1(J+1)^2(J+2)^2 - \mu_0(J+2) - \mu_1(J+1)(J+2)^2$$

$$+ [(2/3) - 2(J+1)/(2J+1)] \, [\lambda_0 + \lambda_1(J+1)(J+2)] , \text{ and}$$

$$d = \langle J, M_J, N{=}J+1, S \mid H \mid J, M_J, N{=}J-1, S \rangle$$

$$= 2\sqrt{J(J+1)} \, (2J+1)^{-1} \, [\lambda_0 + \lambda_1(J^2+J+1)] . \qquad \ldots(3c)$$

In terms of a, b, c, and d, the energy eigenvalues and the corresponding eigenvector coefficients α, β, and γ in Eq. (1) are given by:[11]

$$H_{11} = 2(B_0 + 2B_1) - 2(\mu_0 + 2\mu_1) - (4/3)(\lambda_0 + 2\lambda_1) ,$$

$$\alpha_{11} = \beta_{11} = \gamma_{11} = 0; \qquad \ldots(4a)$$

$$E_0(J) = b, \qquad \alpha_0 = 0, \; \beta_0 = 1, \; \gamma_0 = 0; \qquad \ldots(4b)$$

$$E_\pm(J) = (1/2)(a+c) \pm \sqrt{(1/4)(a-c)^2 + d^2} ,$$

$$\alpha_\pm = d/\sqrt{(a-E_\pm)^2 + d^2} , \; \beta_\pm = 0, \; \gamma_\pm = \alpha_\pm(E_\pm - a)/d . \qquad \ldots(4c)$$

Eqs. (3) and (4) are contained within the APL program ABCD (lines 11-36 in Fig. 7, p. 24). (This program computes the transition matrix elements, as discussed in a later section.)

More generally, for $B_2 \neq 0$, the energy levels are given by Eqs. (5) of Ref. 3, as corrected by Steinbach[7] and Mizushima[22]:

$$E(J=N=n) = B_0 n(n+1) + B_1 n^2(n+1)^2 + B_2 n^3(n+1)^3 + 2\lambda_0/3 + 2\lambda_1 n(n+1)/3 - \mu_0 - \mu_1 n(n+1), \qquad \ldots(5a)$$

$$\begin{aligned} E(J=n-1) = {} & B_0(n^2-n+1) + B_1(n^4-2n^3+7n^2-6n+2) \\ & + B_2(n^6-3n^5+18n^4-31n^3+33n^2-18n+4) - \lambda_0/3 \\ & - \lambda_1(n^2-n+4)/3 - 3\mu_0/2 - \mu_1(7n^2-7n+4)/2 \\ & + \Big[\big[B_0(2n-1) + B_1(4n^3-6n^2+6n-2) \\ & \quad + B_2(6n^5-15n^4+32n^3-33n^2+18n-4) - \lambda_0/(2n-1) \\ & \quad - \lambda_1(7n^2-7n+4)/(6n-3) - \mu_0(2n-1)/2 \\ & \quad - \mu_1(2n^3-3n^2+9n-4)/2\big]^2 \\ & \quad + 4\big[\lambda_0 + \lambda_1(n^2-n+1)\big]^2 n(n-1)/(2n-1)^2 \Big]^{1/2}, \end{aligned} \qquad \ldots(5b)$$

$$\begin{aligned} E(J=n+1) = {} & B_0(n^2+3n+3) + B_1(n^4+6n^3+19n^2+30n+18) \\ & + B_2(n^6+9n^5+48n^4+153n^3+279n^2+270n+108) - \lambda_0/3 \\ & - \lambda_1(n^2+3n+6)/3 - 3\mu_0/2 - \mu_1(7n^2+21n+18)/2 \\ & - \Big[\big[B_0(2n+3) + B_1(4n^3+18n^2+30n+18) \\ & \quad + B_2(6n^5+45n^4+152n^3+279n^2+270n+108) \\ & \quad - \lambda_0/(2n+3) - \lambda_1(7n^2+21n+18)/(6n+9) \\ & \quad - \mu_0(2n+3)/2 - \mu_1(2n^3+9n^2+21n+18)/2\big]^2 \\ & \quad + 4\big[\lambda_0 + \lambda_1(n^2+3n+3)\big]^2 (n+1)(n+2)/(2n+3)^2 \Big]^{1/2}. \end{aligned} \qquad \ldots(5c)$$

where n (denoted 'n' by Steinbach[11] and K by Tinkham[1]) is an

"effective[3] (or pseudo[11]) quantum number" such that $n \rightarrow N$ in the limit, $\lambda/B \rightarrow 0$. In the APL program GENGHZ, listed in Fig. 2, Eqs. (5) are used to compute the energy levels, ENN = $E(J=n) = E_o$, ENNMIN1 = $E(J=n-1) = E_+$, and ENNPLU1 = $E(J=n+1) = E_-$, all in gigahertz (GHz).

The microwave transition frequencies, $f^{\pm}$, are characterized by the selection rules,

$$\Delta K = 0,\ \Delta J = \pm 1 \text{ (Microwave spectrum)} \qquad (6a)$$

and are given by:

$$f^+ = E_o - E_- = FP = ENN - ENNPLU1 = ENN - ELP \qquad (6b)$$

$$f^- = E_o - E_+ = FM = ENN - ENNMIN1 = ENN - ELM \qquad (6c)$$

These frequencies are included in Appendix B (following the output format governed by the APL program PRINT6002), together with the lower state energies, ELP and ELM, relative to the ground state, which is (K = 1, J = 0) in $^{16}O_2$ and $^{18}O_2$ and is (K = 0, J = 1) in $^{16}O^{18}O$. As is well known,[18,21] the homonuclear symmetry of $^{16}O_2$ and $^{18}O_2$ permits only odd-K states to exist, whereas two sets of states, one even in K, the other odd in K, exist in $^{16}O^{18}O$.

The program GENINVCM (Fig. 3) converts the energies to the units of cm^{-1}, i. e., NUNN, NUNNMIN1, and NUNNPLU1 are in cm^{-1} relative to the ground state, and NUNPLU and NUNMIN are the transition frequencies in cm^{-1}.

The submillimeter absorption frequencies are characterized by the selection rules,

$$\Delta K = 2,\ \Delta J = 0,\ 1 \text{ (Submm spectrum)} \qquad (7a)$$

and occur as triplets. With upper states denoted by a single prime (K', J'), and lower states by a double prime (K'', J''), we label the transition frequencies as follows:

```
     ∇ GENGHZ;N;ENJMINUS;ENJPLUS;AB0;AB1;AB2;AL1;AM1;BB1;BB2;BL11;BM0;BM1;MESS0;MESS1;MESS2;ARG1
[1]    ⍝      THIS PROGRAM IS A CORRECTED VERSION OF EQUS. (5A),
[2]    ⍝ (5B), AND (5C) OF W. M. WELCH AND M. MIZUSHIMA, PHYS. REV. A,
[3]    ⍝ VOL. 5, NO. 6, PP. 2692 TO 2695, JUNE 1972.  E(J=N=N) IS HERE
[4]    ⍝ LABELLED AS ENN; E(J=N-1) IS HERE LABELLED ENNMIN1; AND
[5]    ⍝ E(J=N+1) IS HERE LABELLED ENNPLU1.
[6]    ⍝ WITH B0, B1, B2, LAM0, LAM1, MU0, AND MU1 IN GIGAHERTZ,
[7]    ⍝ GENGHZ GENERATES AS OUTPUTS THE ENERGY LEVELS,
[8]    ⍝ ENN, ENNMIN1, AND ENNPLU1, IN GIGAHERTZ.
[9]    B1←-(|B1)
[10]   B2←-(|B2)
[11]   MU0←-(|MU0)
[12]   MU1←-(|MU1)
[13]   N←NINPUT,(NINPUT+2)
[14]   ENJ←(B0×N×(N+1))+(B1×(N*2)×((N+1)*2))+(2×LAM0÷3)+(2×LAM1×N×(N+1)÷3)-(MU0+(MU1×N×(N+1)))
[15]   ENJ←ENJ+(B2×(N*3)×((N+1)*3))
[16]   ENN←((ρN)÷2)↑ENJ
[17]   AB0←(N*2)+1-N
[18]   AB1←(N*4)+(7×(N*2))+2-((2×(N*3))+(6×N))
[19]   AB2←(N*6)+(18×(N*4))+(33×(N*2))+4-((3×(N*5))+(31×(N*3))+(18×N))
[20]   AL1←(N*2)+4-N
[21]   AM1←(7×(N*2))+4-(7×N)
[22]   BB1←(4×(N*3))+(6×N)-((6×(N*2))+2)
[23]   BB2←(6×(N*5))+(32×(N*3))+(18×N)-((15×(N*4))+(33×(N*2))+4)
[24]   BL11←(6×N)-3
[25]   BM0←N-0.5
[26]   BM1←(2×(N*3))+(9×N)-((3×(N*2))+4)
[27]   MESS0←(B0×AB0)+(B1×AB1)+(B2×AB2)-((LAM0÷3)+(LAM1×AL1÷3)+(3×MU0÷2)+(0.5×MU1×AM1))
[28]   MESS1←(B0×((2×N)-1))+(B1×BB1)-((LAM0÷((2×N)-1))+((LAM1×AM1)÷BL11)+(MU0×BM0)+(0.5×MU1×BM1))
[29]   MESS1←MESS1+(B2×BB2)
[30]   MESS2←(LAM0)+(LAM1×AB0)
[31]   ARG1←(MESS1*2)+(4×(MESS2*2)×N×(N-1)×(((2×N)-1)*¯2))
[32]   ENJMINUS←MESS0+(ARG1*0.5)
[33]   E10←MESS0+MESS1
[34]   ENNMIN1←((ρN)÷2)↑ENJMINUS
[35]   →(N[1]≠0)/CONTINUE
[36]   ENNMIN1[2]←E10[2]
[37]   CONTINUE:ENNMIN1[1]←E10[1]
[38]   ENJPLUS←MESS0-(ARG1*0.5)
[39]   ENNPLU1←((ρN)÷2)↓ENJPLUS
[40]   →(N[1]≠0)/0
[41]   ENN[1]←ENNMIN1[1]←ENNPLU1[1]
     ∇
```

Fig. 2: Listing of APL function GENGHZ

```
    ∇ GENINVCM
[1]   ⍝       THIS FUNCTION GENERATES THE ROTATIONAL ENERGY LEVELS
[2]   ⍝ AND MICROWAVE TRANSITION FREQUENCIES IN INVERSE CENTIMETERS.
[3]   ⍝ IT CALLS GENGHZ AS A SUBROUTINE, AND CONVERTS TO INVERSE CM
[4]   ⍝ BY USING AS THE SPEED OF LIGHT, SPEEDOFLIGHT=29.9792458(1.2)
[5]   ⍝ GIGAHERTZ PER INVERSE CENTIMETER (1973 VALUE).
[6]   ⍝       THE ENERGY LEVELS ARE CALLED NUNN, NUNNMIN1, AND
[7]   ⍝ NUNNPLU1, WHILE THE N+ AND N¯ TRANSITION FREQUENCIES ARE
[8]   ⍝ CALLED NUNPLU AND NUNMIN, RESPECTIVELY.  THE 1(0) STATE (FOR
[9]   ⍝ WHICH N=1, J=0) IS TAKEN AS THE ZERO ENERGY LEVEL.
[10]  ⍝       IN THE CASE OF O16=O18, THE 0(1) STATE (FOR WHICH
[11]  ⍝ N=0, J=1) IS TAKEN AS THE ZERO ENERGY LEVEL.
[12]  GENGHZ
[13]  SPEEDOFLIGHT←29.9792458⍝ (UNITS: GHZ PER INVERSE CM)
[14]  →(NINPUT[1]≠0)/CONTINUE
[15]  E10[1]←ENNPLU1[1]
[16]  CONTINUE:NUNN←(ENN-E10[1])÷SPEEDOFLIGHT
[17]  NUNNMIN1←(ENNMIN1-E10[1])÷SPEEDOFLIGHT
[18]  NUNNPLU1←(ENNPLU1-E10[1])÷SPEEDOFLIGHT
[19]  NUNPLU←NUNN-NUNNPLU1
[20]  NUNMIN←NUNN-NUNNMIN1
[21]  →(NINPUT[1]≠0)/0
[22]  NUNMIN[1]←NUNPLU[1]←NUNN[1]←NUNNMIN1[1]←NUNNPLU1[1]←0
    ∇
```

Fig. 3: Listing of APL function GENINVCM

$$\text{NUF:}\quad K' = K''+2,\quad J'-1 = J'' = K'' \tag{7b}$$

$$\text{NUG:}\quad K' = K''+2,\quad J' = J'' = K''+1 \tag{7c}$$

$$\text{NUH:}\quad K' = K''+2,\quad J'-1 = J'' = K''+1 \tag{7d}$$

The program SUBMMO2 (Fig. 4) calculates, in cm^{-1}, the transition frequencies, NUF, NUG, and NUH, as well as the respective lower state energies, ELF, ELG, and ELH = ELG, relative to the rotational ground state ($K = 1$, $J = 0$ for $^{16}O_2$ and $^{18}O_2$, $K = 0$, $J = 1$ for $^{16}O^{18}O$). The results of these calculations for the various sets of values of the molecular parameters, B_0, B_1, etc., are included in Appendix B, together with the equivalents of NUF, NUG, and NUH in GHz.

For the rotational band lying above the first excited vibrational state, the lower state energy relative to the true ground state (for $v = 0$) is given by $\Delta G_{1/2}$ plus the energy relative to the rotational ground state, e. g., ELF. This consideration is important when computing the line strength, and is taken into account in our calculations (via LINESTRENGTHROTVIB, AFCRL5K15UPPER and AFCRL60K1UPPER (see Appendix A)).

In Appendix B, the "laser-magnetic-resonance" or Raman lines studied by Evenson, et al[4,6] are also listed. These lines are characterized by:

$$\text{ERL:}\quad K' = K''+2,\ J' = K',\quad J'' = K'' . \tag{8}$$

The root-mean-square deviation between the Raman lines observed to date[6] and the various predicted frequencies is also given in Appendix B. These lines are of no concern in calculations of atmospheric absorption by molecular oxygen.[17]

Line Strengths

The general expression for the integrated line strength of an isolated magnetic dipole transition between an initial state, $|\psi_i\rangle$ (lower state in absorption), and a final state, $|\psi_f\rangle$ (upper state in absorption), taking into account both absorption and

```
∇ SUBMMO2;N;ENJ;ENJMINUS;ENJPLUS;AB0;AB1;AB2;AL1;AM1;BB1;BB2;BL11;BM0;BM1;MESS0;MESS1;MESS2;ARG1;EDF;EDG;EDH
  ⍝       THIS PROGRAM CALCULATES THE TRANSITION FREQUENCIES,
  ⍝ NUF, NUG, AND NUH (IN THE SUBMM REGION), AND THE ENERGIES
  ⍝ OF THE RESPECTIVE LOWER STATES, ELF, ELG, AND ELH,
  ⍝ ALL GIVEN IN INVERSE CM.  INPUTS REQUIRED: B0, B1, B2,
  ⍝ LAM0, LAM1, MU0, AND NINPUT.
  ⍝ (EXAMPLE: NINPUT←((2×⍳ 27)-1) PRODUCES 1 3 5 ...51 53.)
  'REFNO = ';REFNO
  'NINPUT:  ';NINPUT
  B1←-(|B1)
  B2←-(|B2)
  MU0←-(|MU0)
  MU1←-(|MU1)
  N←NINPUT,(NINPUT+2)
  ENJ←(B0×N×(N+1))+(B1×(N*2)×((N+1)*2))+(2×LAM0÷3)+(2×LAM1×N×(N+1)÷3)-(MU0+(MU1×N×(N+1)))
  ENJ←ENJ+(B2×(N*3)×((N+1)*3))
  ENN←((⍴N)÷2)↑ENJ
  AB0←(N*2)+1-N
  AB1←(N*4)+(7×(N*2))+2-((2×(N*3))+(6×N))
  AB2←(N*6)+(18×(N*4))+(33×(N*2))+4-((3×(N*5))+(31×(N*3))+(18×N))
  AL1←(N*2)+4-N
  AM1←(7×(N*2))+4-(7×N)
  BB1←(4×(N*3))+(6×N)-((6×(N*2))+2)
  BB2←(6×(N*5))+(32×(N*3))+(18×N)-((15×(N*4))+(33×(N*2))+4)
  BL11←(6×N)-3
  BM0←N-0.5
  BM1←(2×(N*3))+(9×N)-((3×(N*2))+4)
  MESS0←(B0×AB0)+(B1×AB1)+(B2×AB2)-((LAM0÷3)+(LAM1×AL1÷3)+(3×MU0÷2)+(0.5×MU1×AM1))
  MESS1←(B0×((2×N)-1))+(B1×BB1)-((LAM0÷((2×N)-1))+((LAM1×AM1)÷BL11)+(MU0×BM0)+(0.5×MU1×BM1))
  MESS1←MESS1+(B2×BB2)
  MESS2←(LAM0)+(LAM1×AB0)
  ARG1←(MESS1*2)+(4×(MESS2*2)×N×(N-1)×(((2×N)-1)*¯2))
  ENJMINUS←MESS0+(ARG1*0.5)
  E10←MESS0+MESS1
  ENNMIN1←((⍴N)÷2)↑ENJMINUS
  ENNMIN1[1]←E10[1]
  ENJPLUS←MESS0-(ARG1*0.5)
  ENNPLU1←((⍴N)÷2)↑ENJPLUS
  ⍝ EDF, EDG, AND EDH ARE IN GIGAHERTZ
  EDF←(((⍴N)÷2)↓ENJMINUS)-ENN
  EDG←(((⍴N)÷2)↓ENJMINUS)-ENNPLU1
  EDH←(((⍴N)÷2)↓ENJ)-ENNPLU1
  →(N[1]≠0)/CONTINUE
  ENNMIN1[2]←E10[2]
  E10[1]←ENN[1]←ENNMIN1[1]←ENNPLU1[1]
  EDF[1]←0
  CONTINUE:SPEEDOFLIGHT←29.9792458⍝  [GHZ PER INVERSE CM]
  ⍝ ELF, ELG, ELH, NUF, NUG, AND NUH ARE IN INVERSE CM.
  ELF←(ENN-E10[1])÷SPEEDOFLIGHT
  ELG←(ENNPLU1-E10[1])÷SPEEDOFLIGHT
  ELH←ELG
  NUF←EDF÷SPEEDOFLIGHT
  NUG←EDG÷SPEEDOFLIGHT
  NUH←EDH÷SPEEDOFLIGHT
∇
```

Fig. 4: Listing of APL function SUBMMO2

stimulated emission under equilibrium conditions at (Kelvin) temperature T, is as follows, in units of $cm^{-1}(\text{molecule } cm^{-2})^{-1}$:

$$S(T) = \frac{8\pi^3}{3hc} \nu_0 \, |\langle \psi_i | \vec{\mu} | \psi_f \rangle|^2 \, (e^{-E_i/kT} - e^{-E_f/kT})/Q(T), \quad (9a)$$

where h = Planck's constant = $6.626176(36)\cdot 10^{-27}$ erg sec,

c = vacuum speed of light = $2.99792458(1.2)\cdot 10^{10}$ cm sec^{-1},

ν_0 = transition frequency (cm^{-1}),

E_i = energy of initial (lower) state (ergs),

E_f = energy of final (upper) state (ergs),

Q(T) = total partition function (state sum) (dimensionless),

and the dipole moment operator is summed over all degenerate levels possessing the same initial and final state energies.[18] Rewriting Eq. (9a) in terms of the dimensionless transition strengths, I(K'',J'';K',J'),[1] and recalling that $E_f - E_i = hc\nu_0$,

$$S(T) = \frac{8\pi^3}{3hc} (g_s^e \, \beta_{Bohr})^2 \, I(K'',J'';K',J') \, \nu_0 \, e^{-E''(hc/kT)} \cdot \left[1 - e^{-\nu_0(hc/kT)}\right]/Q(T), \quad (9b)$$

where g_s^e = free-electron g factor = $2\cdot 1.0011596567(35)$,

β_{Bohr} = Bohr magneton = $9.274078(36)\cdot 10^{-21}$ erg $gauss^{-1}$,

hc/k = second radiation constant = 1.438786(45) cm K,

$E'' = E_i/hc$ = lower state energy (cm^{-1}),

and $$Q(T) = \left[\sum_K (2K+1)\exp(-NUNN\cdot hc/kT) + (2K-1)\exp(-NUNNMIN1\cdot hc/kT) + (2K+3)\exp(-NUNNPLU1\cdot hc/kT)\right]\cdot Q_v(T),$$

$$Q_v(T) \doteq \left[1 - \exp(-\Delta G_{1/2}\cdot hc/kT)\right]^{-1} \text{ (p.123, Ref. 18)}, \quad (10)$$

since for each value of J, there are (2J + 1) degenerate levels.[1] (Recall that NUNN = $(E_0 - E_{grnd})/c$, NUNNMIN1 = $(E_+ - E_{grnd})/c$, and NUNNPLU1 = $(E_- - E_{grnd})/c$, in the notation of Eqs. (6).[11]) The values adopted for the fundamental constants are those of Ref. 13. The use of the free-electron g factor is consistent with our neglect of the Zeeman effect;[1,4,11,17] an error in S(T) of less than 1 part in 10^4 is incurred thereby, while we only require answers correct to three decimal places--to be consistent

with the accuracy of the AFCRL Atmospheric Absorption Line Parameters Compilation[23] which these computations are intended to supplement.

In the microwave region (but not in the submillimeter wave region), $\nu_0 << kT/hc$, so that one may replace the factor in square brackets in Eq. (9b) by its linear approximation, leading to the well-known microwave approximation:[1,11,12]

$$S(T) \doteq \frac{8\pi^3}{3kT} (g_s^e \beta_{Bohr})^2 I(K'',J'';K',J') \nu_0^2 \frac{\exp(-E''hc/kT)}{Q(T)}$$

(Microwave approximation) ...(9c)

(Note that in the optical region, the factor in square brackets in Eq. (9b) is approximately unity, i. e., the induced emission term may be neglected at 300K and below, as in Eq. (3) of Ref. 23.)

Choosing $T = T_s$ = 296K, the standard temperature of the AFCRL compilation,[23] the thermal energy expressed in wavenumbers is $kT/hc = kT_s/hc$ = (296)/(1.438786(45)) = 205.729(6) cm^{-1}, so that Eq. (9b) becomes:

$$S(T_s\text{=296K}) \doteq 1.4353\cdot 10^{-22} I(K'',J'';K',J') \nu_0 \exp(-E''/205.729) \cdot [1 - \exp(-\nu_0/205.729)] /Q(T_s\text{=296K}).$$

...(9d)

Since we desire our computed line strengths to be consistent with those of AFCRL,[23] we must multiply $S(T_s)$ by the relative isotopic abundance of the molecule (our Table I, or Table 3 of Ref. 23), which is 0.99519 for the dominant isotope, $^{16}O_2$. Denoting the resulting quantity by $S_m(T_s)$, whose units are cm^{-1} per molecule of mixed oxygen per cm^2, we obtain an expression like Eq. (9d) with the numerical factor in front replaced by the quantity, $1.4283967\cdot 10^{-22}$ (retaining extra digits to avoid round-off error) which appears in line 22 of LINESTRENGTH2 (Fig. 5).

The rotational state sum $Q(T)/Q_v(T)$ is evaluated by summing Eq. (10) through K = 79 in the program ISOSTATESUM (Fig. 6), and

```
      ∇ LINESTRENGTH2
[1]    ⍝      THIS PROGRAM COMPUTES THE LINE STRENGTHS OF THE MICROWAVE
[2]    ⍝ AS WELL AS THE SUBMILLIMETER WAVE TRANSITIONS OF MOLECULAR
[3]    ⍝ OXYGEN.  ELP, ELM, FP, AND FM MUST HAVE BEEN CALCULATED (E. G.
[4]    ⍝ BY 'PRINT6002' OR A CALLING PROGRAM LIKE 'AFCRL60K25').
[5]    ⍝ THE ROTATIONAL PARTITION FUNCTION, 'SUM', CALCULATED
[6]    ⍝ BY 'ISOSTATESUM' IS ALSO REQUIRED.  THIS PROGRAM CALLS
[7]    ⍝ 'SUBMMO2' TO OBTAIN THE SUBMILLIMETER FREQUENCIES AND
[8]    ⍝ LOWER STATE ENERGIES.  THE MULTIPLICATIVE CONSTANT,
[9]    ⍝ S0, IS THE PRODUCT OF THE RELATIVE ISOTOPIC ABUNDANCE,
[10]   ⍝ (8÷3)×((PI)*3)×((MAGNETICMOMENT)*2)÷(HPLANCK×SPEED-OF-LIGHT),
[11]   ⍝ AND THE RECIPROCAL OF 'SUM', WHERE 'MAGNETICMOMENT' IS THE
[12]   ⍝ PRODUCT OF THE BOHR MAGNETON AND TWICE THE FREE-ELECTRON G-
[13]   ⍝ FACTOR, AND HPLANCK IS PLANCK'S CONSTANT.
[14]   KT←205.729×(TEMP÷296)
[15]   'TEMP = ';TEMP;'K;     KT = ';KT;' INVERSE CM;     X = ';X
[16]   S0←1
[17]   →(X=1)/ONE;→(X=2)/TWO;→(X=3)/THREE
[18]   →0;'INCORRECT VALUE FOUND FOR ''X''; CALL ''PARAMSTEIN'''
[19]   NLP←ELP÷SPEEDOFLIGHT;NLM←ELM÷SPEEDOFLIGHT
[20]   THREE:S0←4.1616E¯6÷0.00407
[21]   TWO:S0←S0×0.00407÷0.99519
[22]   ONE:S0←S0×1.4283967E¯22÷SUM
[23]   SUBMMO2
[24]   NUP←FP÷SPEEDOFLIGHT;NUM←FM÷SPEEDOFLIGHT
[25]   NLP←ELP÷SPEEDOFLIGHT;NLM←ELM÷SPEEDOFLIGHT
[26]   ⍝ ELP, ELM, FP AND FM ARE CALCULATED IN 'PRINT6002' AND 'AFCRL60K25'
[27]   SF←S0×F×NUF×(*(-ELF÷KT))×(1-(*(-NUF÷KT)))
[28]   SG←S0×G×NUG×(*(-ELG÷KT))×(1-(*(-NUG÷KT)))
[29]   SH←S0×H×NUH×(*(-ELH÷KT))×(1-(*(-NUH÷KT)))
[30]   SP←S0×PP×NUP×(*(-NLP÷KT))×(1-(*(-NUP÷KT)))
[31]   SM←S0×MM×NUM×(*(-NLM÷KT))×(1-(*(-NUM÷KT)))
      ∇
```

Fig. 5: Listing of APL function LINESTRENGTH2

```
    ∇ ISOSTATESUM;KT;NINPUT;TERM1;TERM2;TERM3;TERM
      ⍝     THIS PROGRAM COMPUTES THE ROTATIONAL PARTITION FUNCTION
      ⍝ OR STATE SUM FOR MOLECULAR OXYGEN.  IT IS BASED ON THE ENERGY
      ⍝ LEVELS OF STEINBACH AND GORDY.  THE PROGRAM SETS TEMP EQUAL
      ⍝ TO KELVIN TEMPERATURE TYPED IN RESPONSE TO 'QUAD' (⎕) PROMPT.
      ⍝      AT 296K, THE LAST TERM INCLUDED IN THE STATE SUM FOR 016=016
      ⍝ CONTRIBUTES ONLY 8.06E¯17; FOR 016=018, THE LAST TERM IS 8.40E¯16.
      NINPUT←((2×⍳40)-1)
      →(X≠2)/SKIP
      NINPUT←(⍳80)-1
      SKIP:GENINVCM
      'PLEASE TYPE IN KELVIN TEMPERATURE: '
      TEMP←⎕
      KT←205.729×(TEMP÷296)
      TERM1←(1+2×NINPUT)×(*((-NUNN)÷KT))
      TERM2←(¯1+2×NINPUT)×(*((-NUNNMIN1)÷KT))
      TERM3←(3+2×NINPUT)×(*((-NUNNPLU1)÷KT))
      →(X≠2)/ADD
      TERM1[1]←TERM2[1]←0;TERM3[1]←(TERM3[1])÷3
      ADD:TERM←TERM1+TERM2+TERM3
      SUM←+/TERM
      CLASSICAL←(1.5×KT×SPEEDOFLIGHT)÷B0
      'ROTATIONAL STATE SUM = ';SUM;'  (EXACT VALUE)'
      →(X=2)/BYPASS
      'CLASSICAL APPROXIMATION = (3÷2)×(KT÷B0)×SPEEDOFLIGHT = ';CLASSICAL
      CONTINUE:RATIO←SUM÷CLASSICAL
      'RATIO = ';RATIO
      'TEMPERATURE = ';TEMP;'K;    ISOTOPE = ';ISOTEXT[X;];'.'
      →0
      BYPASS:CLASSICAL←2×CLASSICAL
      'CLASSICAL APPROXIMATION = (3×KT÷B0)×SPEEDOFLIGHT = ';CLASSICAL
      →(X=2)/CONTINUE
    ∇
```

Fig. 6: Listing of APL function ISOSTATESUM

compared with the classical values,[1,12,18] $3kT/2hcB_0$ for $^{16}O_2$ and $^{18}O_2$, and $3kT/hcB_0$ for $^{16}O^{18}O$. (The state sum contains twice as many rotational states in a heteronuclear diatomic molecule as in a homonuclear one.[18]) Appendix D lists some results.

The vibrational partition function $Q_V(T)$ has been approximated by unity at $T = T_s = 296K$. This is consistent with the AFCRL approximation of $Q_V(T_s) \doteq 1.000$ (Table 2, Ref. 23). More precisely, in the harmonic oscillator approximation given by Eq. (10),

$$\begin{aligned}[Q_V(T_s{=}296K)]^{-1} &= 1 - \exp(-\Delta G_{1/2} \cdot hc/kT_s) \\ &= 1 - \exp(-1556.378/205.729) \\ &\doteq 1 - 5.1818 \cdot 10^{-4} \doteq 0.999482, \qquad (11)\end{aligned}$$

leading to an overestimate of 5.2 parts in 10^4 in the values for $S_m(T_s)$ as given in this report. Thus, the third decimal place in the line strengths tabulated in this document will be in error by one unit, at most.

We now turn to the calculation of the normalized transition matrix elements (squared), $I(K'',J'';K',J')$, i. e., of the quantities F, G, H, PP, and MM in lines 27-31 of LINESTRENGTH2.

<u>Transition Matrix Elements</u>

Steinbach[11] has shown that the normalized magnetic-dipole transition matrix elements, both those for the microwave "fine structure" (or spin-reorientation[18]) transitions and those for the "forbidden" submillimeter rotational transitions, may be written in terms of the Wigner 6-j symbols[20,24] and the eigenvector coefficients, α and γ, appearing in Eqs. (1) and (4). With $n'(J')$ denoting the final state, $n(J)$ the initial state, i. e., employing n instead of K and dropping the double primes, the results are displayed in Table II. These expressions may be simplified further: First, we note that for fixed $J \neq 0$, $\alpha_- = \gamma_+$ and $\alpha_+ = -\gamma_-$ (<u>cf</u>. Tables 8, 9, and 10 of Ref. 11). To prove this formally, let us first note that $d > 0$ from Eq. (3c).

Table II: Normalized Magnetic Dipole Transition Matrix Elements

Transition $n(J) \rightarrow n'(J')$	Normalized Matrix Element[a] $\lvert\langle \psi_f \lvert \vec{\mu} \rvert \psi_i \rangle\rvert^2/(g_s^e\,\beta_{Bohr})^2$
Fine Structure Transitions:	
$n(n-1) \rightarrow n(n)$:	$6(2n-1)(2n+1)\,\gamma_i^2 \begin{Bmatrix} 1 & n & n \\ n-1 & 1 & 1 \end{Bmatrix}^2$
$n(n+1) \rightarrow n(n)$:	$6(2n+1)(2n+3)\,\alpha_i^2 \begin{Bmatrix} 1 & n & n \\ n+1 & 1 & 1 \end{Bmatrix}^2$
Rotational Transitions:	
$n(n) \rightarrow n+2\ (n+1)$:	$6(2n+1)(2n+3)\,\alpha_f^2 \begin{Bmatrix} 1 & n+1 & n \\ n & 1 & 1 \end{Bmatrix}^2$
$n(n+1) \rightarrow n+2\ (n+1)$:	$6(2n+3)^2 \left[\alpha_i\alpha_f \begin{Bmatrix} 1 & n+1 & n \\ n+1 & 1 & 1 \end{Bmatrix} + \gamma_i\gamma_f \begin{Bmatrix} 1 & n+1 & n+2 \\ n+1 & 1 & 1 \end{Bmatrix} \right]^2$
$n(n+1) \rightarrow n+2\ (n+2)$:	$6(2n+3)(2n+5)\,\gamma_i^2 \begin{Bmatrix} 1 & n+2 & n+2 \\ n+1 & 1 & 1 \end{Bmatrix}^2$

[a] After Table 2, Ref. 11. The quantities $\begin{Bmatrix} j_1 & j_2 & j_3 \\ J_1 & J_2 & J_3 \end{Bmatrix}$ are Wigner's 6-j symbols (see Ref. 24).

Letting $(c - a)/2d = \xi$ in Eq. (4c), we find that

$$x_{\pm} \equiv (E_{\pm} - a)/d = \xi \pm \sqrt{1 + \xi^2},$$

so that $x_+ x_- = \xi^2 - 1 - \xi^2 = -1$, and $x_- = -1/x_+$. Letting $x_+ = \tan\theta$, Eq. (4c) then states that $\alpha_+ = \cos\theta$, $\gamma_+ = \alpha_+ x_+ = \sin\theta$. Since $x_- = -1/x_+ = -\text{ctn}\,\theta$, Eq. (4c) also states that $\alpha_- = \sin\theta$, $\gamma_- = \alpha_- x_- = -\sin\theta\,\text{ctn}\,\theta = -\cos\theta$. Thus, $\alpha_- = \gamma_+$, $\alpha_+ = -\gamma_-$, QED.*

Next, using Eq. (C.36) of Ref. 24 to evaluate the 6-j symbols, we obtain:

$$\begin{Bmatrix} 1 & n & n \\ n-1 & 1 & 1 \end{Bmatrix}^2 = \frac{(n+1)}{6n(2n+1)} \; ; \; \begin{Bmatrix} 1 & n & n \\ n+1 & 1 & 1 \end{Bmatrix}^2 = \frac{n}{6(n+1)(2n+1)} \; ;$$

$$\begin{Bmatrix} 1 & n+1 & n \\ n & 1 & 1 \end{Bmatrix}^2 = \frac{n}{6(n+1)(2n+1)} \; ; \; \begin{Bmatrix} 1 & n+1 & n \\ n+1 & 1 & 1 \end{Bmatrix} = -\sqrt{\frac{(n+2)}{6(n+1)(2n+3)}} \; ;$$

$$\begin{Bmatrix} 1 & n+1 & n+2 \\ n+1 & 1 & 1 \end{Bmatrix} = \sqrt{\frac{(n+1)}{6(n+2)(2n+3)}} \; ; \; \begin{Bmatrix} 1 & n+2 & n+2 \\ n+1 & 1 & 1 \end{Bmatrix}^2 = \frac{(n+3)}{6(n+2)(2n+5)} \, .$$

Inserting these results into the expressions in Table II, noting that $\left[\sqrt{\frac{n+2}{n+1}} + \sqrt{\frac{n+1}{n+2}}\right]^2 = (2n+3)^2(n+1)/(n+2)$, and replacing n by K once again, we obtain $I(K'',J'';K',J') = \dfrac{|\langle \psi_f | \vec{\mu} | \psi_i \rangle|^2}{(g_s^e \beta_{Bohr})^2}$:

$$MM = I(K,K-1;K,K) = [\gamma_+(K-1)]^2 \, (2K-1)(K+1)/K \tag{12}$$

$$PP = I(K,K+1;K,K) = [\alpha_-(K+1)]^2 \, (2K+3)K/(K+1) \tag{13}$$

$$F = I(K,K;K+2,K+1) = [\gamma_-(K+1)]^2 (2K+3)\cdot K/(K+1) \tag{14}$$

$$G = I(K,K+1;K+2,K+1) = [\gamma_-(K+1)]^2 (2K+3)\cdot [\alpha_-(K+1)]^2 \cdot (2K+3)^2 (K+1)/(K+2) \tag{15}$$

$$H = I(K,K+1;K+2,K+2) = [\gamma_-(K+1)]^2 (2K+3)\cdot (K+3)/(K+2) \tag{16}$$

where the J-dependence of the alphas and gammas in Eqs. (12)-(16) is indicated explicitly by their arguments in parentheses.

---

* From Eq. (1), it is intuitively clear that θ represents the small (but non-zero) angle in Hilbert space through which $|\psi_{\pm}\rangle$ are rotated away from their Hund's case (b) approximations.

The equivalents of these six equations are contained in lines 41, 42, 45, and 46 of the program ABCD (Fig. 7). (To avoid possible division by zero, the dyadic APL function X REPLACE Y is used. It is listed following ABCD in Fig. 7. It replaces zero values of J and K by a small number during arithmetic operations (ABCD line 10) and, at the end of the calculations (line 41), it undoes the effects of this replacement.)

It is clear from Eqs. (14)-(16) that the submillimeter transitions would be strictly forbidden were γ_- actually zero (pure Hund's case (b) coupling) instead of merely small.[11] On the other hand, γ_+ (and α_-) are nearly equal to their case-(b) values of unity; thus, the microwave transitions (Eqs. (12)-(13)) are negligibly affected by the deviation from case (b) coupling.[1] The various types of allowed transitions[1,7,8,11] are shown in the energy level diagrams of Fig. 8.

The existence of a common factor in Eqs. (14)-(16) not only simplifies the calculation of the strengths of the "forbidden" lines, but also enables us to exhibit the asymptotic behavior of their relative strengths, since $\alpha_-(K+1) \to 1$ as $K \to \infty$, i. e., $F : G : H \sim 1 : 4 : 1$. This is in agreement with the correspondence-principle argument of Gebbie, et al.[8] On the other hand, in their final results (Table VII, column 6, and Eq. (63a)), Tinkham and Strandberg[1] (T-S) incorrectly and "unphysically" predicted "F"-type transitions to be much weaker than "H"-type transitions,[8] an error carried over into the Russian literature.[25] Nevertheless, the intermediate results of T-S (Eqs. (60) and Table V) were essentially correct,[1] as pointed out by Gebbie, et al.[8] Indeed, one easily deduces that $F : H = K(K+2)/(K+1)(K+3)$ both from our Eqs. (14),(16) as well as from the fifth and eighth of Eqs. (60) of T-S.[1] Thus, except for $I(K,K;K+2,K+1)$, our results for the transition matrix elements, given in Appendix B, are in close agreement with Table V of T-S.[1]

To within the tabulated accuracy and limited spectral

```
    ∇ ABCD;J;Q;QQ;APC;AMC;ROOT;A;B;C;D;ALPHAG;BETAG;GAMMAG;COMMON
[1]   ⍝   THIS PROGRAM CALCULATES THE PARAMETERS A, B, C, D, AND THE VARIOUS ALPHAS, BETAS, AND GAMMAS
[2]   ⍝ APPEARING IN W. R. STEINBACH'S THESIS, AND USES THEM TO COMPUTE THE TRANSITION MATRIX ELEMENTS
[3]   ⍝ FOR MOLECULAR OXYGEN.  THE OUTPUTS ARE IN THE NOTATION OF TINKHAM AND STRANDBERG, I. E.,
[4]   ⍝ I(K'',J'';K',J').  SHORTHAND NOTATION: PP=I(K,K+1;K,K); MM=I(K,K-1;K,K); F=I(K,K;K+2,K+1);
[5]   ⍝ G=I(K,K+1;K+2,K+1); AND H=I(K,K+1;K+2,K+2).  IN ADDITION, ALPHAP, ALPHAM, ALPHA0,
[6]   ⍝ BETAP, BETAM, BETA0, GAMMAP, GAMMAM, AND GAMMA0 ARE AVAILABLE AS OUTPUT.
[7]   ⍝     THIS PROGRAM CALLS PARAMSTEIN AS A SUBROUTINE
[8]   PARAMSTEIN
[9]   J←(K+1),K;K←NINPUT
[10]  J←1E¯40 REPLACE J;K←1E¯40 REPLACE K
[11]  Q←J×(J+1)
[12]  A←(B0×J×(J-1))+(B1×((J×(J-1))*2))+(MU0×(J-1))+(MU1×J×((J-1)*2))+((2÷3)-(2×J÷(1+2×J)))×(LAM0+(LAM1×J×(J-1)))
[13]  B←(B0×Q)+(B1×Q*2)+((2÷3)×(LAM0+LAM1×Q))-(MU0+MU1×Q)
[14]  QQ←(J+1)×(J+2)
[15]  C←(B0×QQ)+(B1×QQ×QQ)+(((2÷3)-(2×(J+1)÷(1+2×J)))×(LAM0+LAM1×QQ))-((MU0×(J+2))+(MU1×QQ×(J+2)))
[16]  D←(2×(Q*0.5)÷(1+2×J))×(LAM0+(LAM1×(Q+1)))
[17]  ⍝    WE NOW COMPUTE THE EIGENENERGIES AND EIGENVECTOR COEFFICIENTS IN TERMS OF A, B, C, AND D.
[18]  EGRND←(2×(B0+2×B1))-(2×(MU0+(2×MU1)+((2÷3)×(LAM0+2×LAM1))))
[19]  E0J←B
[20]  APC←A+C;AMC←A-C
[21]  ROOT←(((AMC*2)÷4)+D*2)*0.5
[22]  EPJ←(APC÷2)+ROOT;EMJ←(APC÷2)-ROOT
[23]  ⍝      IN THE GROUND STATE, THE FOLLOWING SPECIAL VALUES HOLD:
[24]  ALPHAG←0;BETAG←0;GAMMAG←1
[25]  ⍝     FOR STATES WITH N (= K) = J, ONLY BETA IS NONZERO.
[26]  ALPHA0←(ρK)ρ0;BETA0←(ρK)ρ1;GAMMA0←(ρK)ρ0
[27]  BETAP←BETAM←(ρK)ρ0
[28]  ALPHAP←D÷(((A-EPJ)*2)+D*2)*0.5
[29]  ALPHAM←D÷(((A-EMJ)*2)+D*2)*0.5
[30]  GAMMAP←ALPHAP×(EPJ-A)÷D
[31]  GAMMAM←ALPHAM×(EMJ-A)÷D
[32]  ⍝       AT THIS POINT, THESE VECTORS ARE NOT YET IN PROPER CORRESPONDENCE TO NINPUT = K.  WE NOW
[33]  ⍝ APPEND THE ''GROUND STATE'' VALUES AND THEN MAKE SURE THE DIMENSION IS THE SAME AS THAT OF K.
[34]  ALPHAP←(ρK)↑(ALPHAG,ALPHAP);ALPHAM←(ρK)↑ALPHAM
[35]  BETAP←(ρK)↑(BETAG,BETAP);BETAM←(ρK)↑BETAM
[36]  GAMMAP←(ρK)↑(GAMMAG,GAMMAP);GAMMAM←(ρK)↑GAMMAM
[37]  ⍝       THE ALPHAS, BETAS, AND GAMMAS ARE GLOBAL VARIABLES (WHICH MAY BE OUTPUT AT WILL).
```

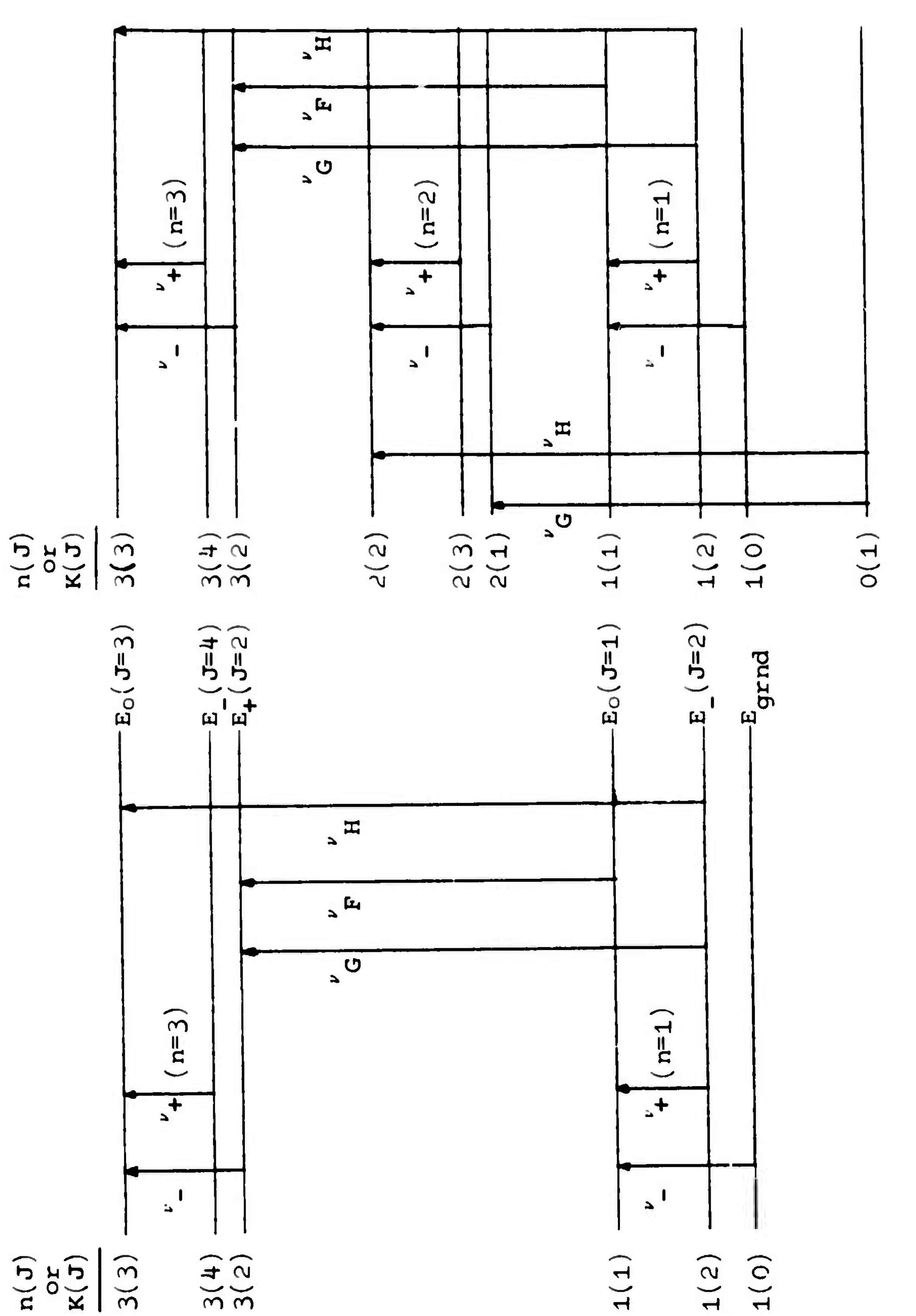
Fig. 7: Listings of the APL functions ABCD and X REPLACE Y

```
[38]  ⍝     MAKE ARRAYS EOJ, EPJ, AND EMJ CONSISTENT WITH K+1 (=J FOR EPJ, EMJ) OR K (=J FOR EOJ).
[39]  EOJ←(ρK)↑B;EPJ←(ρK)↑EPJ;EMJ←(ρK)↑EMJ
[40]  ⍝ WE NOW COMPUTE THE TRANSITION MATRIX ELEMENTS, NOTING THAT THE ALPHA AND GAMMA ARRAYS ARE SIMPLY RELATED.
[41]  PP←(ALPHAM*2)×K×(3+2×K)÷(K+1)
[42]  MM←(GAMMAP*2)×(K+1)×(¯1+2×K)÷K
[43]  →(K[1]≥1)/SKIP
[44]  EOJ←(ρK)↑(1↓EOJ);MM←(ρK)↑(0,(GAMMAP*2)×(K+2)×(1+2×K)÷(K+1))
[45]  SKIP:COMMON←(GAMMAM*2)×(3+2×K)
[46]  F←COMMON×K÷(K+1);G←COMMON×((ALPHAM×(3+2×K))*2)÷((K+1)×(K+2));H←COMMON×(K+3)÷(K+2)
[47]  K←0 REPLACE K;PP←0 REPLACE PP;MM←0 REPLACE MM;F←0 REPLACE F;G←0 REPLACE G;H←0 REPLACE H
[48]  'K = ';K;'
'
[49]  'I(K,K+1;K,K)
      ';PP
[50]  'I(K,K¯1;K,K)
      ';MM
[51]  '
'
[52]  'I(K,K;K+2,K+1)
      ';F
[53]  'I(K,K+1;K+2,K+1)
      ';G
[54]  'I(K,K+1;K+2,K+2)
      ';H
    ∇



    ∇ RESULT←NEWZERO REPLACE VECTOR;ZERO;MASK;XSUB
[1]   ZERO←1E¯40
[2]   MASK←(|VECTOR)≤ZERO
[3]   XSUB←MASK/MASK×⍳ρMASK
[4]   VECTOR[XSUB]←NEWZERO
[5]   RESULT←VECTOR
    ∇
```

Fig. 7 (Cont'd): Listings of the APL functions ABCD and REPLACE



(a) Transitions allowed in $^{16}O_2$ and $^{18}O_2$

(b) Transitions allowed only in $^{16}O^{18}O$

Fig. 8: Allowed magnetic dipole transitions (After Ref. 11)

coverage of Steinbach's thesis,[11] all of our transition matrix elements in Appendix B agree with those of his Tables 11-13. Steinbach has also noted[11] the discrepancy of these results with those tabulated by Tinkham and Strandberg.[1] We have been unable to ascertain whether or not our results also agree with those of Gebbie, et al, who only give integrated line strengths in units of 10^{-6} cm^{-2} atm^{-1}.[8] In Appendix E, we list our results for integrated line strengths in these units, taken to refer to 273K, so that $1(\text{cm-atm})_{STP} = 2.686754(84) \cdot 10^{19}$ molecules/cm^2.[23] The results in Appendix E exhibit discrepancies of as much as a factor of two with the results of Gebbie, et al.,[8] but inasmuch as no temperature is specified in Ref. 8, the precise magnitude of the discrepancies is difficult to ascertain.

<u>Line Widths</u>

For molecular oxygen at pressures characteristic of altitudes below 40 km, pressure-broadening predominates.[26] Near an isolated transition frequency, pressure-broadened molecular absorption is well-approximated by a Lorentz line shape with half-width $\boldsymbol{\alpha} = \boldsymbol{\alpha}_0 \cdot p$ at half-maximum points, where p is the pressure.[23,27] (Bold-face alphas are used to distinguish them from the quantities appearing in Eqs. (1), (4), (13), and Table II.) Then the absorption at the peak of the spectral line will be given by $S_0 = S(T)/\pi\boldsymbol{\alpha}$, where S(T) is given by Eq. (9),[23,27]* and will fall off away from the peak in accordance with whatever lineshape is most suited to the particular spectral region:[28] Van Vleck-Weisskopf in the microwave region,[12] "kinetic" in the submillimeter region,[29,30] and Lorentz or "super-Lorentz" in the infrared and visible regions.[31]

Of the line parameters required to perform atmospheric transmission calculations,[23] the linewidths for oxygen are the least accurately characterized ones, unfortunately. The experimental values of $\boldsymbol{\alpha}_0$ (in MHz/torr) measured for $^{16}O^{16}O$ in the microwave region by several investigators between 1952 and 1968 (at 300K)

* S(T) actually should be replaced by $S_m(T)$. (See page 17.)

have been summarized conveniently in a review article by P. H. Krupenie.[32] These experimental values, converted to cm^{-1}/atm and rounded to two significant figures, have been employed in the line parameter compilations for molecular oxygen contained in this report. (1 MHz/torr = (760)/(29979.2458) ≐ 0.02535 cm^{-1} per atm.) To the degree of uncertainty (as much as 25%) inherent in the data,[26,33] no correction has been made for a possible isotope effect in the line widths; instead, a crudely linear interpolation on K was made from Krupenie's Table 34,[32] to describe the widths expected for the even-K states in $^{16}O^{18}O$ (see Fig. 8), and the tabulated values themselves[32] were used for the odd-K states in all three isotopes considered.

Other than the relatively crude results in Ref. 8, no data are available in the literature concerning the widths of the submillimeter lines of molecular oxygen. If one assumes that the line widths depend on the value of K in the lower state, and one notes that "G" and "H" transitions with $K'' = n$ possess the same lower states as the microwave "+" transitions with the same n (see Fig. 8), then one may safely assume that these two types of submillimeter transition possess the same line widths as the associated microwave "+" transition. Somewhat arbitrarily, the line widths for "F" transitions have been taken as the arithmetic mean of the linewidths of the "+" and "-" transitions with the same value of n.

An alternative procedure of even less accuracy would have been to use the electron-optical data[34-36] to deduce the submillimeter line widths. However, unlike the K-dependence found for the microwave line widths, the J-dependence exhibited by the line widths in the visible region[34-36] is unlikely to be correct for the submillimeter lines.

For lines corresponding to higher values of K than have been measured in the microwave region, a lower limit of 0.032 cm^{-1}/atm has been assumed. The line widths are entered in

lines 27-30 of AFCRLFILE (Fig. 9), lines 29-31 of AFCRL60K15 (Fig. 10), and similarly in the other "AFCRL"-format-setting programs listed (by name and short comment only) in Appendix A.

The determination of line widths near room temperature and 1 atm for molecular oxygen is complicated by the demonstrated breakdown of the independent-line approximation in the microwave region.[26,33] The microwave line widths have been treated in the past by assuming α_0 to be pressure-dependent,[37,38] and more recently by means of several interacting-line theories.[39-42] Since the microwave-line-width situation in molecular oxygen is under current active study at several institutions,[43] it was decided to use the Krupenie compilation[32] to obtain interim ($\pm$10 to 25%) values for the line widths, pending further results expected during the next year.*

Line Parameters in "AFCRL Format"

McClatchey, et al[23] have described their compilation of molecular spectroscopic parameters for seven infrared-active molecules which occur naturally in the terrestrial atmosphere. As of 1 April 1975,[44] all of the submillimeter lines of oxygen were absent from the AFCRL computer tape, and the microwave lines were all represented as having the line width, 0.060 cm^{-1} per atm. It was in order to supply the data on molecular oxygen which was missing (and is required as input to the RRI SLAM program[45]) that the calculations described in this Research Note were undertaken. Having performed the calculations described in the preceding sections, we therefore made use of the APL output-formatting program ΔFMT (described in Ref. ~~46~~ 52) to cast our results into a form compatible with the AFCRL format.[23] This was accomplished by means of the eight APL programs whose names begin with "AFCRL" in the defined-function list in Appendix A. Two of these (for $^{16}O^{16}O$ in the vibrational ground state) are

* Since S(T) has been calculated fairly precisely in this report, measurements of peak absorption in the submillimeter region should yield line-width values which can help clarify the microwave line-width situation (because of the relationships discussed above).

```
    ∇ AFCRLFILE;X;NU;S;EL;W;K;JU;KU;JL;KL;TX;TEXT;CARD
[1]   ⍝      THIS PROGRAM LISTS THE FREQUENCY, LINE STRENGTH, LINEWIDTH, ENERGY
[2]   ⍝ OF LOWER STATE, QUANTUM NUMBERS OF UPPER AND LOWER STATE, LINE TYPE ID,
[3]   ⍝ DATE, ISOTOPE, AND MOLECULE, IN THE FORMAT OF THE AFCRL LINE PARAMETERS
[4]   ⍝ COMPILATION.  UNITS ARE: INVERSE CM, INVERSE CM PER MOLECULE PER CM SQ,
[5]   ⍝ INVERSE CM/ATM, INVERSE CM, V', J', K', V'', J'', K'', (SF, SG, OR SH)
[6]   ⍝ MONTH AND YEAR, SECOND DIGITS OF ISOTOPIC SPECIES (66 MEANS O16=O16),
[7]   ⍝ AND MOLECULE (7 = OXYGEN).
[8]   'REFNO = ';REFNO
[9]   'TEMP = ';TEMP
[10]  NU←(3×⍴F)⍴0
[11]  S←(3×⍴F)⍴0
[12]  EL←(3×⍴F)⍴0
[13]  X←1
[14]  LOOP:NU[(3×X)-2]←NUF[X]
[15]  NU[(3×X)-1]←NUG[X]
[16]  NU[(3×X)]←NUH[X]
[17]  S[(3×X)-2]←SF[X]
[18]  S[(3×X)-1]←SG[X]
[19]  S[(3×X)]←SH[X]
[20]  EL[(3×X)-2]←ELF[X]
[21]  EL[(3×X)-1]←ELG[X]
[22]  EL[(3×X)]←ELH[X]
[23]  X←X+1
[24]  →(X≤⍴F)/LOOP
[25]  ⍝ LINEWIDTHS BASED ON KRUPENIE COMPILATION (1972);
[26]  ⍝ SEE PAGE 28 OF REPORT FOR DISCUSSION.
[27]  W←0.048 0.045 0.045 0.045 0.044 0.044 0.044 0.043 0.042 0.042 0.042 0.041 0.041
[28]  W←W,0.041 0.04 0.04 0.041 0.039 0.039 0.038 0.038 0.038 0.036 0.034 0.034
[29]  W←W,0.037 0.036 0.036 0.036 0.035 0.035 0.035 0.035 0.035 0.035 0.032 0.032
[30]  W←W,((¯36+(3×⍴F))⍴0.032)
[31]  K←NINPUT
[32]  JU←JU[⍋(JU←(K+1),(K+1),(K+2))]
[33]  KU←KU[⍋(KU←(K+2),(K+2),(K+2))]
[34]  JL←JL[⍋(JL←K,(K+1),(K+1))]
[35]  KL←KL[⍋(KL←K,K,K)]
[36]  TX←(3×⍴F)⍴('F','G','H')
[37]  TEXT←'F10.5,E10.3,BF5.3,F10.3,⎕   0   ⎕,I2,X1,I2,X6,⎕0   ⎕,I2,X1,I2,⎕  S⎕,A1,X5,⎕75   66   7⎕'
[38]  X←1
[39]  LOOP2:CARD←TEXT ⍙FMT(NU[X];S[X];W[X];EL[X];JU[X];KU[X];JL[X];KL[X];TX[X])
[40]  →(CARD[;21]≠((⍴(CARD[;21]))⍴'0'))/PRINT
[41]  CARD[;21]←(⍴(CARD[;21]))⍴' '
[42]  PRINT:⎕←CARD
[43]  X←X+1
[44]  →(X≤⍴NU)/LOOP2
[45]  ⍝  CALLING SEQUENCE: ABCD, ISOSTATESUM, AFCRL60K15, AFCRLFILE.
    ∇
```

Fig. 9: Listing of APL function AFCRLFILE

```
    ∇ AFCRL60K15;Z;ZZ;NU;S;EL;W;K;JU;KU;JL;KL;TX;TEXT;CARD
      ⍝       THIS PROGRAM LISTS THE FREQUENCY, LINE STRENGTH, LINEWIDTH, ENERGY
      ⍝ OF LOWER STATE, QUANTUM NUMBERS OF UPPER AND LOWER STATE, LINE TYPE ID,
      ⍝ DATE, ISOTOPE, AND MOLECULE, IN THE FORMAT OF THE AFCRL LINE PARAMETERS
      ⍝ COMPILATION.  UNITS ARE: INVERSE CM, INVERSE CM PER MOLECULE PER CM SQ,
      ⍝ INVERSE CM/ATM, INVERSE CM, V', J', K', V'', J'', K'', (K+ OR K¯).
      ⍝ MONTH AND YEAR, SECOND DIGITS OF ISOTOPIC SPECIES (66 MEANS O16=O16).
      ⍝ AND MOLECULE (7 = OXYGEN).
      →(X=1)/CONTINUE
      →0;'WRONG ISOTOPE: THIS PROGRAM IS ONLY FOR O16=O16.'
      CONTINUE:FP←ENN-ENNPLU1;FM←ENN-ENNMIN1;GENGHZ
      ⍝ FP AND FM ARE THE FREQUENCIES FOR THE K+ AND K¯ LINES (SEE 'PRINT6002')
      ELP←ENNPLU1-ENNMIN1[1];ELM←ENNMIN1-ENNMIN1[1]
      ⍝ ELP AND ELM ARE THE LOWER STATE ENERGIES IN GIGAHERTZ (SEE 'PRINT6002')
      LINESTRENGTH2⍝ CALCULATES STRENGTHS, SP AND SM.
      ⍝ PP AND MM MATRIX ELEMENTS FOR K+ AND K¯ LINES ARE COMPUTED BY ABCDLP.
      NU←(2×⍴PP)⍴0
      S←(2×⍴PP)⍴0
      EL←(2×⍴PP)⍴0
      Z←1
      LOOP:NU[(2×Z)-1]←(FP[Z])÷SPEEDOFLIGHT
      NU[(2×Z)]←(FM[Z])÷SPEEDOFLIGHT
      S[(2×Z)-1]←SP[Z]
      S[(2×Z)]←SM[Z]
      EL[(2×Z)-1]←(ELP[Z])÷SPEEDOFLIGHT
      EL[(2×Z)]←(ELM[Z])÷SPEEDOFLIGHT
      Z←Z+1
      →(Z≤⍴PP)/LOOP
      ⍝ LINEWIDTHS BASED ON KRUPENIE COMPILATION (1972).
      W←0.045 0.05 0.044 0.047 0.042 0.044 0.041 0.044 0.04 0.043 0.039 0.041 0.038 0.039
      W←W,0.034 0.038 0.036 0.038 0.035 0.037 0.035 0.035 0.032 0.038
      W←W,((¯24+(2×⍴PP))⍴0.032)
      K←NINPUT
      KL←KU←JU←JU[⍋(JU←(K,K))]
      JL←,⍉((2,(⍴K))⍴((K+1),(K-1)))
      TX←(2×⍴PP)⍴('+','-')
      TEXT←'F10.5,E10.3,BF5.3,F10.3,⎕   0   ⎕,I2,X1,I2,X6,⎕0   ⎕,I2,X1,I2,X1,I2,A1,X5,⎕75   66   7⎕'
      SORT←⍋NU
      ZZ←1
      LOOP2:Z←SORT[ZZ]
      CARD←TEXT ΔFMT(NU[Z];S[Z];W[Z];EL[Z];JU[Z];KU[Z];JL[Z];KL[Z];KL[Z];TX[Z])
      →(CARD[;21]≠((⍴(CARD[;21]))⍴'0'))/PRINT
      CARD[;21]←(⍴(CARD[;21]))⍴' '
      PRINT:⎕←CARD
      ZZ←ZZ+1
      →(ZZ≤⍴NU)/LOOP2
    ∇
```

Fig. 10: Listing of APL function AFCRL60K15

listed in Figs. 9 and 10. The format specifications in line 37 of AFCRLFILE (Fig. 9) and line 36 of AFCRL60K15 (Fig. 10) are equivalent to the FORTRAN format:

```
 FREQ    STRENGTH WIDTH  E''       V'   J'    K'
(F10.5,  E10.3,  F5.3,  F10.3,3X,I1,3X,I2,1X,I2,6X,

V''  J''    K''    ID      DATE   ISO   MO
I1,3X,I2,1X,I2,1X,A3,5X, I2,2X,I2,2X,I1)
```

This format is in accordance with the one given on page 6 of Ref. 23, except that the frequency is given to five decimal places (F10.5) instead of three (F10.3).

In Appendix F, the contents of the eight files generated by AFCRLFILE, AFCRLK2,...,AFCRL60K35 are listed. (There are two files each for the three isotopes ($^{16}O^{16}O$, $^{16}O^{18}O$, $^{18}O^{18}O$) in the vibrational ground state (v = 0) and $^{16}O^{16}O$ in the first excited vibrational state (v = 1); one for the submillimeter lines, the other for the microwave lines.) As indicated by the heading at the beginning of each file listing, the line parameters were generated by using Steinbach and Gordy[7] for the molecular parameters (B_0, B_1, B_2, λ_0, λ_1, μ_0, μ_1) in the vibrational ground state, and Albritton, et al[5] for those of $^{16}O^{16}O$ in the v = 1 state. The APL function LINESTRENGTH2 (Fig. 5) or its abbreviated form, LINESTRENGTH22 (see Appendix A), was used to compute the line strengths at 296K. (For convenience, the vibrational partition function was ignored, i. e., set equal to unity, as discussed above.) The line widths were derived from Krupenie's compilation[32] in the manner indicated in the preceding section.

For clarity, at the top of each page in Appendix F, the columns have been labelled with the appropriate headings: <u>freq</u>uency (cm^{-1}); line <u>strength</u> (cm^{-1}/(molecule cm^{-2})); line <u>width</u> (cm^{-1} atm^{-1}); lower state energy <u>E''</u> (cm^{-1}); upper state quantum numbers, <u>V'</u>, <u>J'</u>, and <u>K'</u>; lower state quantum numbers, <u>V'</u>', <u>J'</u>', and <u>K'</u>'; shorthand line <u>id</u>entification (K+ or K- for

the microwave lines; SF, SG, or SH for the submillimeter lines); month and last digit of year in date of computation (75 = July 1975); isotope code (66 = $^{16}O^{16}O$, 68 = $^{16}O^{18}O$, 88 = $^{18}O^{18}O$); and molecular constituent (7 = oxygen).

The eight files listed in Appendix F were merged into a single file, ordered by frequency by means of a FORTRAN program (SRWRTMERGE) which employed the XDS Sigma 9 MERGE processor. A threshold criterion was then applied to the resulting merged file to select only the most "significant" lines: only lines whose strengths exceeded $3.7 \cdot 10^{-30}$ cm^{-1} per molecule cm^{-2} (the "Existing Intensity Minimum at T = 296K" given for O_2 in Table 3 of McClatchey, et al[23]) were to be retained. (The zero frequency "lines" of zero strength in the listings for $^{16}O^{18}O$ in Appendix F--artifacts arising from the manner in which the APL programs were executed--are removed at this stage.) The resulting file, OXYGENEXIST, is listed in Appendix G. (This file was created by means of another FORTRAN program, NOSIG, which allows one to remove "cards" whose strengths lie below a user-specified level from any card-image file written in "AFCRL format".)

The file OXYGENEXIST in Appendix G contains the parameters of all "fine-structure" and "rotational" lines of the molecules, $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$, which can be expected to be of significance in atmospheric absorption problems. A deck of punched cards containing the card-image records in this file was sent to AFCRL on 28 July 1975.

Summary and Comments

Calculations performed at RRI have been described which give current best estimates of the line parameters of all significant microwave and submillimeter wave absorption lines of the molecular oxygen isotopes, $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$, at zero magnetic field. The transition frequency (given to the

nearest .00001 cm^{-1} ± 0.3 MHz) and energy of the lower state (quoted to the nearest .001 cm^{-1}) have absolute accuracies on the order of .001 cm^{-1} as judged by the degree of consistency between measured[3-7] and predicted values (Appendix B). These results are certainly in agreement with recent low-resolution stratospheric Fourier-transform spectroscopic measurements[46] of the submillimeter emission by the earth's atmosphere between 35 and 200 cm^{-1}. The rms deviation between our calculated frequencies and the twenty-seven observed lines of $^{16}O^{16}O$ short of 200 cm^{-1} is .05 cm^{-1}, which is within the .07 cm^{-1} (unapodized) resolution of the measurements.

Integrated line strengths at 296K, accurate to within one unit in the third decimal place, have been calculated; the new results are in apparent disagreement (Appendix E) with earlier published line strengths[8] for $^{16}O^{16}O$, by a factor of approximately two. We note that these earlier line strengths,[8] together with the strength data on water and ozone lines from the AFCRL compilation,[23] have been used recently to deduce the temperature of the cosmic background radiation,[47] as well as to determine the water content of the stratosphere.[48,49] A closer look at the data analyses may be warranted in both cases[46-49] to determine whether the deduced results are significantly affected by the change in oxygen line strengths to the new values we report.

The least certain parameters are the line widths, for which we chose interim values, based on Ref. 32. The line widths in the microwave region are currently under intensive study[41-43] so that we should be able to improve on the line width estimates during the next year. We pointed out that direct study of the submillimeter line widths could help to clarify some of the issues attending the more complicated problem of the microwave line widths. The line widths which we give here must be viewed as uncertain to ±10 to 25%.

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APPENDIX A

Brief Description of APL Notation and Output Formats

The intent of this Appendix is to enable the reader unfamiliar with APL to verify that the algebraic expressions given in this report have been implemented properly within the APL "functions" (programs), and to explain the APL output formats in Appendices B and E.

APL[50-52] is an interactive, time-sharing-oriented, programming language which is especially suited to working with arrays in one or more dimensions with a minimum of looping or branching. It uses a special symbol set,[51,52] many of whose elements have intuitively clear meanings (e. g., the parenthesis pairs, (and), or the binary operators, +,−,÷, etc.), but the same symbol may play different roles, depending on the context (e. g., ⎕ or ρ). The following rules are of principal importance in following the APL programs listed in this report:

1. Operations are performed from right to left, with no hierarchy between addition, multiplication, etc. In most of the programs listed, parentheses have been used liberally to make the resulting expressions look more like ordinary algebra. Examples: ÷ means "multiply by reciprocal of everything to the right"; −/ means "sum the alternating series resulting from the placement of a binary minus between all elements of the array sequence beyond the slash (/)".

2. Operators can be unary or binary (÷B means "take reciprocal of B"; A÷B means "A divided by B" where A and B are arrays of the same "rank" (dimensions) or scalar); functions can be

niladic (e. g., GENGHZ), monadic, or dyadic (e. g., REPLACE, or the intrinsic[51,52] function ∆FMT).

3. Substitution is indicated by an arrow pointing left; M ← 5 (equivalent to FORTRAN: M = 5) is not the same as M = 5 in APL, the latter (equivalent to FORTRAN: M.EQ.5) having 0 or 1 ("no" or "yes") as a result. (If M is an array, the logical relations return arrays of the same dimensions, filled with zeros and ones.)

4. APL has two kinds of minus signs. Negative numbers, such as in the exponents in Appendix C or in front of the elements of VECB1 in PARAMSTEIN, are preceded by the unary, upper-case minus, ¯; negation or subtraction is indicated by the binary, ordinary-looking, minus, -. Example: If A is ¯5 4 0 ¯3, the result of the operation -A is: 5 ¯4 0 3.

5. While standard texts[50-52] should be referred to for the meanings and syntax of the special APL symbols, the following occur sufficiently often in our programs to merit discussion:

, (comma) used as a binary operator means "concatenate": 0 1 2, 0 1 produces the result 0 1 2 0 1. (See lines 27-30 of AFCRLFILE.) Used as a unary operator (as in line 34 of AFCRL60-K15), it means "ravel", or string out as a vector. (The special symbol ⍉ means "transpose".)

; (semi-colon) is used for separation of independent expressions, as well as (in headers--line 0) to indicate local variables defined only within the program (as opposed to global variables such as SPEEDOFLIGHT, defined "forever").

⋆ (asterisk) denotes exponentiation: A⋆B means A^B (binary operator); ⋆B means e^B (unary operator).

| (vertical) denotes absolute value: |A means $|A|$.

⍳ (iota) is the "index" operator, with unity as the origin: ¯1 ×⍳5 produces the result ¯1×(1 2 3 4 5) or ¯1 ¯2 ¯3 ¯4 ¯5.

ρ (rho) used monadically is the <u>dimension</u> operator: ρ A returns an integer vector with the dimensions of A. Example: ρ(2 ¯1 5) returns 3. (The integer vector has <u>one</u> element in this case since A was a vector.) ρ (rho) used dyadically is the <u>reshape</u> operator: A ρ B returns an array whose dimensions are given by the left (vector) argument A, and whose (initial) values are given by the right argument B. If B does not contain sufficient values, it is recycled. Example: 2 5 ρ 3 returns the 2-by-5 array,

3 3 3 3 3 .
3 3 3 3 3

↑ and ↓ are the "take" and "drop" operators. Examples: Let A be the array 5 3 2 4 0 3. Then 3↑A yields 5 3 2; 3↓A yields 4 0 3. See also lines 34-39 of the function ABCD (Fig. 7).

[and] (brackets) enclose line numbers in program listings and also indicate array indices. Examples: If A ← 2 3 1 0, then A[3] is 1; if M is a two-dimensional matrix, M[5;] picks out the fifth row (all columns) of M.

6. Branching is indicated by the arrow pointing right, and the syntax is illustrated by the example: →(x≠2)/NEXT which is equivalent to the FORTRAN statement IF (X.NE.2.0) GO TO NEXT.

7. The APL system carries out <u>all</u> calculations to approximately 16 significant digits. The results are displayed <u>rounded off</u> to the number of digits specified by a system command,)DIGITS. Even after output display is called for, the full 16-digit-accuracy is retained in the system memory.

8. The "default" output format for the vector quantities in Appendix B is to be understood as a list, in one-to-one correspondence with the array NINPUT given at the start of each page. In Appendix E, the "take 5" operation has been applied before printing out results relating to Ref. 8, so that these arrays refer to the first five values of NINPUT. (Similar comments hold for the experimental values of ERL in Appendix B.) Note that <u>trailing zeros are suppressed on display</u>.

TABLE A-1: DIRECTORY OF APL FUNCTIONS CREATED FOR THIS REPORT

FUNCTION NAME	COMMENT	PAGE *
ABCD	USED TO CALCULATE TRANSITION MATRIX ELEMENTS	24-25
ABCDLP	VERSION OF ABCD USED FOR LINE PRINTER OUTPUT	N/A
ABCDUPPER	VERSION OF ABCD FOR V = 1 STATES OF 016=016	N/A
AFCRLFILE	LISTS LINE PARAMETERS OF 016=016 FOR V = 0	30
AFCRLK2	VERSION OF AFCRLFILE FOR 016=018 (V = 0)	N/A
AFCRLK3	VERSION OF AFCRLFILE FOR 018=018 (V = 0)	N/A
AFCRL5K15UPPER	VERSION OF AFCRLFILE FOR 016=016 FOR V = 1	N/A
AFCRL60K1UPPER	LISTS '60 GHZ' LINES OF 016=016 FOR V = 1	N/A
AFCRL60K15	LISTS '60 GHZ' LINES OF 016=016 FOR V = 0	31
AFCRL60K25	VERSION OF AFCRL60K15 FOR 016=018 (V = 0)	N/A
AFCRL60K35	VERSION OF AFCRL60K15 FOR 018=018 (V = 0)	N/A
COMPARAMAN	COMPUTES RMS DIFFERENCES BETWEEN PREDICTED AND OBSERVED LASER 'RAMAN' LINES	N/A
FREQLIST	PRINTS OUTPUT OF PARAMSTEINLP, SUBMMO2, PRINT6002, AND COMPARAMAN (SEE APPENDIX B)	N/A
GBBSTRENGTH	PRINTS OUTPUT OF LINESTRENGTH22 AND COMPARES WITH RESULTS OF REF. 8 (SEE APPENDIX E)	N/A
GENGHZ	GENERATES ENERGY LEVELS IN GIGAHERTZ	12
GENINVCM	CONVERTS GENGHZ OUTPUT TO INV CM AND GENERATES MICROWAVE TRANSITION FREQUENCIES (ALSO INV CM)	13
ISOSTATESUM	COMPUTES ROTATIONAL PARTITION FUNCTION	19
ISOSTATESUMLP	VERSION OF ISOSTATESUM FOR LINE PRINTER OUTPUT	N/A
LINESTRENGTHROTVIB	VERSION OF LINESTRENGTH2 FOR 016=016, V = 1	N/A
LINESTRENGTH2	COMPUTES LINE STRENGTHS FOR ALL OXYGEN LINES	18
LINESTRENGTH22	COMPUTES LINE STRENGTHS OF SUBMILLIMETER LINES	N/A
PARAMETERS	GIVES B0, B1, B2, LAM0, LAM1, MU0, MU1 ACCORDING TO ANY ONE OF REFS. 1 THROUGH 6 FOR 016=016	73
PARAMETERSLP	VERSION OF PARAMETERS FOR LINE PRINTER OUTPUT	N/A
PARAMSTEIN	GIVES B0, B1, B2, LAM0, LAM1, MU0, MU1 ACCORDING TO REF. 7 FOR ANY OF THREE ISOTOPES; SETS NINPUT AND TEMPERATURE	8
PARAMSTEINLP	VERSION OF PARAMSTEIN FOR LINE PRINTER OUTPUT	N/A
PARAMSTEINUPPER	VERSION OF PARAMETERS FOR 016=016, V = 1 (REF. 5)	74
PRINTGHZ	PRINTS OUTPUT OF GENGHZ	N/A
PRINTINVCM	PRINTS OUTPUT OF GENINVCM	N/A
PRINTSTATESUM	PRINTS STATE SUM VS. TEMPERATURE (SEE APPENDIX D)	N/A
PRINTSTRENGTH2	PRINTS OUTPUT OF LINESTRENGTH2	N/A
PRINTSUBMMO2	PRINTS OUTPUT OF SUBMMO2	N/A
PRINT6002	CALCULATES MICROWAVE TRANSITIONS, LOWER STATE ENERGIES, AND LASER 'RAMAN' LINES (IN GHZ), AND PRINTS RESULTS (SEE APPENDIX B)	N/A
REPLACE	BINARY FUNCTION WHICH REPLACES 'ZERO' VALUES	25
SUBMMO2	CALCULATES SUBMILLIMETER TRANSITION FREQUENCIES AND LOWER STATE ENERGIES (IN INVERSE CM)	15

* LISTINGS OF APL FUNCTIONS MENTIONED HERE BUT NOT APPEARING EXPLICITLY (MARKED N/A IN THIS COLUMN) ARE AVAILABLE FROM THE AUTHOR UPON REQUEST.

APPENDIX B

Molecular "Rotational" Parameters, Millimeter and Submillimeter Wave Transition Matrices, Transition Frequencies, and Lower State Energies in the Ground ($^3\Sigma_g^-$, v = 0) State of $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$, and in the First Excited Vibrational State (v = 1) of $^{16}O_2$, According to References 1 through 7

For each of the ten sets of parameters studied, there are three pages of computer printout. The first of the three pages gives the rotational parameters, B0, B1, B2, LAM0, LAM1, MU0, and MU1 in GHz and in cm^{-1}, the Reference number, isotope code, the array of K-values, and the corresponding arrays of normalized transition matrices. The second page repeats the Reference number and array of K-values (NINPUT), followed by the submillimeter frequencies (cm^{-1} and GHz) and lower state energies (cm^{-1}) with respect to the ground state. The third page repeats the Reference number and NINPUT, followed by the microwave transition frequencies and lower state energies with respect to the ground state (GHz) and the predicted and observed "laser-magnetic-resonance" lines[6] and their rms difference in MHz and cm^{-1}.

The sequence of the ten sets of parameters is as follows: Ground vibrational state of $^{16}O^{16}O$ (v' = v'' = 0), in order of Reference number (1 through 7); Ground states of $^{16}O^{18}O$, $^{18}O^{18}O$ (Ref. 7); first excited vibrational state (v' = v'' = 1) of $^{16}O^{16}O$ (Ref. 5). (In the last case, $\Delta G_{1/2}$ is not included in the lower state energy, as discussed in the text on p. 14.)

```
THE PARAMETERS ACCORDING TO TINKHAM AND STRANDBERG
      (REF. 1) ARE AS FOLLOWS:

A0 = 43.1029 GHZ = 1.437757984 INVERSE CM;
A1 = -0.00014714499 GHZ = -4.908392325E-6 INVERSE CM;
A2 = 0 GHZ = 0 INVERSE CM;

LAM0 = 59.50157 GHZ = 1.984758736 INVERSE CM;
LAM1 = 5.678E-5 GHZ = 1.893976933E-6 INVERSE CM;

MU0 = -0.25267 GHZ = -0.008428163993 INVERSE CM;
MU1 = 0 GHZ = 0 INVERSE CM.

TEMP = 296   REFNO = 1   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.45196758  6.710354733  10.80289208  14.85056609  18.87965109  22.89924847  26.91335004  30.9239832  34.93228715
      38.93895134  42.94441752  46.94898182  50.95285018  54.95617028  58.95905076  62.96157333  66.96380063  70.9657815
      74.96755456  78.96915074  82.97059515  86.97190834  90.97310731  94.97420626  98.97521711  102.97615  106.9770134
I(K,K-1;K,K)
      2  6.538633547  10.73656757  14.81539485  18.8578617  22.88442557  26.90261358  30.91584825  34.92591044  38.93381849
      42.94019697  46.94545021  50.94985158  54.9535925  58.95681103  62.95960926  66.9620643  70.96423548  74.96616919
      78.96790223  82.96946419  86.97087909  90.97216665  94.97334324  98.97442251  102.975416  106.9763334


I(K,K;K+2,K+1)
      0.04801242004  0.03964526658  0.03044125341  0.02443391254  0.02034890746  0.01741820113  0.01522139115  0.0135168003
      0.01215729513  0.01104865784  0.01012793027  0.00935151092  0.008688277233  0.008115433893  0.007615909952  0.00717667223
      0.006787600558  0.006440718451  0.006129654977  0.005849260756  0.00559532901  0.005364389627  0.005153554908  0.004960402489
      0.004782885384  0.004619262115  0.004468041875
I(K,K+1;K+2,K+1)
      0.3924195254  0.2128270418  0.1465747365  0.111901612  0.09054753909  0.07607063869  0.06561002092  0.05769946803
      0.05150943269  0.04653515144  0.04245180768  0.03904088056  0.03614994067  0.03366941462  0.03151851034  0.02963634836
      0.02797618267  0.02650152421  0.02518347406  0.02399884768  0.02292882929  0.02195798943  0.02107355627  0.02026486734
      0.01952295165  0.01884020734  0.01821015041
I(K,K+1;K+2,K+2)
      0.1280331201  0.06343242652  0.04174800468  0.03102719053  0.02466534238  0.02046334119  0.01748508522  0.01526603328
      0.01354992646  0.01218398358  0.01107152625  0.01014842229  0.009370467889  0.008706212606  0.008132673586  0.007632662021
      0.007193093578  0.006803785977  0.006456739823  0.006145564772  0.005865098134  0.005611123826  0.005380165124
      0.005169329559  0.004976191276  0.00479870071  0.004635114453
```

```
REFNO = 1
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

             THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF: 12.2925742  23.8643608  35.3972662  46.9139459  58.4183923  69.9106627  81.3898344  92.8544497  104.303035  115.733727
     127.144794  138.534423  149.900778  161.24201   172.55626   183.841665  195.096353  206.318453  217.506088  228.657382
     239.770456  250.84343   261.674424  272.861555  283.802943  294.696705  305.540958

NUG: 14.1693627  25.8139385  37.3850231  48.9298923  60.4581758  71.9721127  83.4716627  94.9558898  106.423447  117.872778
     129.302209  140.709998  152.094358  163.453477  174.785522  186.088649  197.361002  208.600721  219.80594   230.97479
     242.105397  253.195887  264.244383  275.249008  286.207883  297.119128  307.980862

NUM: 16.2536938  27.8255334  39.3585222  50.8753555  62.3799059  73.8723506  85.3517268  96.8166242  108.265427  119.696415
     131.107808  142.497792  153.864534  165.206182  176.52088   187.806762  199.061958  210.284595  221.472799  232.624692
     243.738394  254.812027  265.84371   276.831561  287.773699  298.668241  309.513305

          THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF: 3.96109688  18.3380022  44.2139579  81.5847231  130.444172  190.784295  262.595195  345.865094  440.580325  546.72534
     664.282703  793.233095  933.555313  1085.22627  1248.22098  1422.5126   1608.07238  1804.86969  2012.87201  2232.04496
     2462.35224  2703.7557   2956.21527  3219.68902  3494.13313  3779.50189  4075.7477

ELG: 2.08430838  16.3884244  42.226201   79.5688167  128.404389  188.722845  260.513367  343.763701  438.459913  544.586288
     662.125288  791.05782   931.361738  1083.0148   1246.99172  1420.26561  1605.80773  1802.58742  2010.57216  2229.72755
     2460.0173   2701.40384  2953.84831  3217.30157  3491.72819  3777.07946  4073.3078

ELM: 2.08430838  16.3884244  42.226201   79.5688167  128.404389  188.722845  260.513367  343.763701  438.459913  544.586288
     662.125288  791.05752   931.361732  1083.0148   1245.99172  1420.26561  1605.80773  1802.58742  2010.57216  2229.72755
     2460.0173   2701.40324  2953.84531  3217.30157  3491.72819  3777.07946  4073.3078

          THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

  NUF        (GHZ)
     368.522103  715.435538  1061.18334  1406.44591  1751.33934  2095.86894  2440.00585  2783.70779  3126.92632  3469.60988
     3811.70503  4153.15751  4493.91226  4833.91384  5173.10684  5511.43446  5848.84153  6185.27161  6520.66849  6854.97587
     7188.13745  7520.09686  7850.79772  8180.18364  8508.19819  8834.78495  9159.88747
  NUG        (GHZ)
     424.786807  773.882408  1120.7748   1466.88127  1812.49051  2157.66966  2502.41749  2846.70596  3190.49469  3533.737
     3876.38272  4218.37961  4559.67415  4900.21197  5239.93814  5578.79734  5916.73399  6253.6923   6589.61632  6924.45  7258.1372
      7590.62173  7921.84732  8251.75768  8580.29648  8907.40737  9233.03396
  NUM        (GHZ)
     487.273481  834.188506  1179.93881  1525.20479  1870.10253  2214.63736  2558.7804   2902.48938  3245.71585  3588.40824
     3930.51319  4271.97634  4612.74267  4952.75675  5291.96285  5630.30507  5967.72736  6304.17357  6639.58748  6973.91281
     7307.09323  7639.0724   7969.79393  8299.20143  8627.23846  8953.84862  9278.97544
```

```
REFNO = 1
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53


        THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16-O16 ARE AS FOLLOWS:

FP:  56.2647039  58.44687  59.5914529  60.4353529  61.151168  61.8007158  62.4116423  62.9981712  63.5683689  64.1271513
     64.6776855  65.2221038  65.7618944  66.2981279  66.8315937  67.3628869  67.8924649  68.4206844  68.9478283  69.4741234
     69.999754  70.5248711  71.0496  71.8740449  72.098294  72.6224218  73.1464918

FM:  118.750697  62.4866746  60.3060983  59.1640137  58.3235206  57.6120207  56.9676967  56.3629024  55.7834142  55.2211658
     54.671241  54.130473  53.5967293  53.0685218  52.54478  52.0247143  51.5077295  50.9933686  50.4812746  49.9711648
     49.4629121  48.9560325  48.4506748  47.9466139  47.4437453  46.9419811  46.4412467


        THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4859932  491.312605  1265.90966  2385.41311  3849.46673  5657.76855  7809.99426  10305.7765  13144.6975  16326.2862
     19850.0167  23715.3078  27921.5223  32467.9668  37393.892  42578.492  48140.9046  54040.2112  60275.437  66845.5503
     73749.4634  80986.0318  88554.0546  96452.2744  104679.378  113233.994  122114.696

ELM: 0  487.2728  1265.19501  2386.68445  3852.29438  5661.95725  7815.43821  10312.4118  13152.4823  16335.1922  19860.0232
     23726.3995  27933.6875  32481.1964  37368.1788  42593.8301  48157.2893  54057.6386  60253.9035  66865.0533  73770.0003
     81007.6006  88576.6835  96475.9019  104704.032  113259.674  122141.401


        THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 431.008778  775.741636  1120.34736  1464.76943  1808.95136  2152.83664  2496.36875  2839.4912  3182.147[illegible]8  3524.28109
     3865.83551  4206.75424  4546.98078  4886.45562  5225.13126  5562.94219  5899.8349  6235.75289  6570.63965  6904.43868
     7237.09348  7568.54753  7898.74433  8227.62738  8559.14017  8881.22619  9205.82895


        THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
        OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
     THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 1 AND THOSE OBSERVED IS:
     0.0779761657 GHZ = 77.9761657 MHZ = 0.00260100491 INVERSE CM.
```

```
THE PARAMETERS ACCORDING TO WILMEIT AND BARRETT
      (REF. 2) ARE AS FOLLOWS:

B0 = 43.100589 GHZ = 1.437680897 INVERSE CM)
B1 = -0.00014 GHZ = -4.669897333E-6 INVERSE CM)
B2 = 0 GHZ = 0 INVERSE CM)

LAM0 = 59.501346 GHZ = 1.98475126 INVERSE CM)
LAM1 = 5.845E-5 GHZ = 1.949682136E-6 INVERSE CM)

MU0 = -0.2525917 GHZ = -0.008425552187 INVERSE CM)
MU1 = -2.455E-7 GHZ = -8.188998537E-9 INVERSE CM.

TEMP = 296   REFNO = 2   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1)K,K)
      2.451982934  6.710351231  10.8028898  14.8505647  18.8796504I  22.89924837  26.91335046  30.92398409  34.9322847
      38.93895307  42.94441965  46.94898432  50.95285305  54.95617351  58.95905434  62.96157727  66.96380492  70.96578614
      74.96755954  78.96915608  82.97060083  86.97191437  90.9731137  94.97421301  98.97522421  102.9761574  106.9770213
I(K,K-1)K,K)
      2  6.538621158  10.73656197  14.81539172  18.85785994  22.88442474  26.90261347  30.91564873  34.92591144  38.93381997
      42.94019888  46.94545253  50.94985429  54.95359559  58.95681449  62.95961309  66.96206849  70.96424002  74.96617409
      78.96790749  82.9694698  86.97088505  90.97217297  94.97334991  98.97442953  102.9754234  106.9763411


I(K,K)K+2,K+1)
      0.04801706559  0.03964876905  0.03044353464  0.02445296  0.02034958707  0.01741829286  0.01522096825  0.01351591142
      0.01215597389  0.01104692815  0.01012580951  0.009349011909  0.008685409946  0.008112204379  0.007612323816  0.007172733099
      0.006783310856  0.006436079613  0.006124667751  0.005843924757  0.005589643656  0.005358353649  0.005147166545  0.004953659527
       0.004775785192  0.004611180167  0.004460217782
I(K,K+1)K+2,K+1)
      0.3924567513  0.212845733  0.1465856896  0.1119079375  0.09055055993  0.07607103898  0.06560819909  0.05769567533
      0.05150383665  0.04652786833  0.04244429205  0.03903044972  0.03613801055  0.03365601795  0.03150367101  0.02962005342
      0.02795850377  0.02648243859  0.02516298531  0.0239769563  0.02290553312  0.02193328396  0.02104747349  0.02023732157
      0.01949397123  0.01880978004  0.01817826352
I(K,K+1)K+2,K+2)
      0.1280455082  0.06343803048  0.04175113322  0.0310289473  0.02466616615  0.02046244895  0.01748459943  0.01526502937
      0.01354845387  0.01218207615  0.01106920791  0.01014571031  0.009367374944  0.008702747993  0.008128844412  0.007628478603
      0.007188547608  0.006798885645  0.006451486325  0.006139958468  0.005859138671  0.005604810225  0.005373495854  0.005162302259
       0.004968804121  0.004790950458  0.004626997798
```

```
REFNO = 2
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2918502  23.8631552  35.3957897  46.9125382  58.4173647  69.9105379  81.3911871  92.8579938  104.309434  115.74388
      127.159643  138.555002  149.928213  161.27752  172.601156  183.897348  195.164319  206.400287  217.603469  228.77208
      239.904333  250.998441  262.052613  273.065063  284.033998  294.957629  305.834166

NUG:  14.1686401  25.8127231  37.3835307  48.9284254  60.457128  71.9719696  83.4730017  94.9593808  106.429852  117.882952
      129.317099  140.730642  152.121889  163.489118  174.830589  186.144551  197.42924  208.682889  219.903723  231.089965
      242.239836  253.351953  264.423331  275.453385  286.439929  297.381175  308.275335

NUH:  16.2529581  27.8243171  39.3870365  50.8739008  62.3788739  73.8722246  85.3530821  96.8201281  108.271839  119.706585
      131.12268  142.518401  153.892006  165.241735  176.565829  187.862508  199.129995  210.366511  221.570272  232.739493
      243.872386  254.967165  266.02204  277.035822  288.004922  298.929348  309.80671

          THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF:  3.96108476  18.337253  44.2120023  81.5812977  130.439311  190.778422  262.589215  345.860482  440.579223  546.730644
      664.298156  793.26338  933.606141  1085.30447  1248.33461  1422.67101  1608.28631  1805.15139  2013.2353  2232.50532
      2462.92692  2704.46381  2957.07786  3220.72918  3495.37608  3780.97507  4077.48088

ELG:  2.08429488  16.3876851  42.2242612  79.5654105  128.399548  188.71699  260.5074  343.759095  438.458805  544.591571  662.1407
       791.087739  931.412465  1083.09287  1246.10518  1420.42381  1606.02139  1802.86879  2010.93504  2230.18743  2460.59142
      2702.1107  2954.70714  3218.34086  3492.97015  3778.55153  4075.03971

ELH:  2.08429488  16.3876851  42.2242612  79.5654105  128.399548  188.71699  260.5074  343.759095  438.458805  544.591571  662.1407
       791.087739  931.412465  1083.09287  1246.10518  1420.42381  1606.02139  1802.86879  2010.93504  2230.18743  2460.59142
      2702.1107  2954.70714  3218.34086  3492.97015  3778.55153  4075.03971

          THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF        (GHZ)
      368.5004  715.399396  1061.13908  1406.40252  1751.30853  2095.8652  2440.0464  2783.81262  3127.11817  3469.91422
      3812.15018  4153.77445  4494.73475  4834.97842  5174.45249  5513.10381  5850.87909  6187.72494  6523.58789  6858.41442
      7192.15097  7524.74394  7886.13971  8186.28463  8815.12504  8842.60727  9168.67764
 NUG        (GHZ)
      424.765145  773.84597  1120.73006  1466.83729  1812.4591  2157.66537  2502.45764  2846.81062  3190.68671  3534.042
      3876.82909  4218.99851  4560.49949  4901.28044  5241.28921  5580.47324  5918.77971  6256.15561  6592.54776  6927.90287
      7262.16759  7593.28847  7927.21203  8257.88474  8587.25304  8915.26335  9241.86205
 NUH        (GHZ)
      487.251427  834.152043  1179.89427  1525.16118  1870.07159  2214.63358  2558.82103  2902.59442  3245.90806  3588.71313
      3930.95905  4272.59418  4613.56629  4953.82268  5293.3104  5631.97629  5969.76708  6306.62935  6642.50965  6977.35446
      7311.11021  7643.72331  7975.14013  8305.30703  8634.17034  8961.6764  9287.77152
```

```
REFNO = 2
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

        THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16=O16 ARE AS FOLLOWS:

FP:  56.264745  58.4465748  59.5909771  60.4347779  61.1505671  61.800167  62.4112322  62.9979965  63.5685371  64.1277813
     64.6789074  65.2240593  65.7547369  66.3020223  66.8367167  67.369427  67.9006221  68.4306706  68.959867  69.48845
     70.0166156  70.5445267  71.0723201  71.600112  72.1280021  72.6560769  73.1844116

FM:  118.750334  62.4862826  60.3060722  59.1642148  58.3238842  57.6124905  56.9682115  56.3633926  55.7838  55.2213565
     54.6711348  54.1299865  53.5956778  53.0667988  52.5422374  52.0211923  51.5030568  50.9873618  50.4737388  49.9618933
     49.4515865  48.9426225  48.4348385  47.9280975  47.4222834  46.9172963  46.4130501

        THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4855886  491.290441  1265.85151  2385.311  3849.32161  5657.59303  7809.81538  10305.6384  13144.6643  16326.4446
     19850.4788  23716.2138  27923.0432  32470.3075  37357.2935  42583.2344  48147.3101  54048.6465  60286.316  66859.3372
     73766.675  81007.2407  88579.8917  96483.4317  104716.611  113278.125  122166.617

ELM: 0  487.250733  1265.13641  2386.58196  3852.14829  5661.78071  7815.2584  10312.273  13152.449  16335.351  19860.4866
     23727.3079  27935.2123  32483.5427  37371.5879  42598.5827  48163.7077  54066.0898  60304.8021  66878.8638  73787.2401
     81028.8426  88602.5292  96507.1037  104741.316  113303.864  122193.388

        THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 430.986682  775.705468  1120.30329  1464.7264  1808.92102  2152.83341  2496.4098  2839.59642  3182.33953  3524.58535
     3866.28014  4207.37012  4547.80185  4887.52066  5226.47368  5564.60687  5901.86645  6238.19868  6573.54978  6907.86601
     7241.0936  7573.17878  7904.06781  8233.70691  8562.04234  8889.02032  9214.58711

        THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
        OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
     THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 2 AND THOSE OBSERVED IS:
     0.213373325 GHZ = 213.373325 MHZ = 0.007117368 INVERSE CM.
```

```
THE PARAMETERS ACCORDING TO WELCH AND MIZUSHIMA
      (REF. 3) ARE AS FOLLOWS:

B0 = 43.100518 GHZ = 1.437678529 INVERSE CM;
B1 = -0.0001449629 GHZ = -4.835441858E-6 INVERSE CM;
B2 = -1.57E-10 GHZ = -5.236956295E-12 INVERSE CM;

LAM0 = 59.501342 GHZ = 1.984751131 INVERSE CM;
LAM1 = 5.847E-5 GHZ = 1.950349265E-6 INVERSE CM;

MU0 = -0.2525865 GHZ = -0.008425378733 INVERSE CM;
MU1 = -2.464E-7 GHZ = -8.219019306E-9 INVERSE CM.

TEMP = 296   REFNO = 3   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.451982623  6.710350719  10.8028891  14.8505638  18.87964931  22.89924706  26.91334893  30.92398234  34.93228651
      38.93895089  42.94441724  46.9489817  50.9528502  54.95617043  58.98905104  62.9615/373  66.96380116  70.96578214  74.9675553
      78.9691516  82.97059611  86.97190941  90.97310849  94.97420754  98.9752185  102.9761515  106.977015
I(K,K-1;K,K)
      2  6.538620329  10.73656115  14.8153907?  18.8578588  22.8844234  26.90261193  30.91584698  34.92590947  38.93381778
      42.94019647  46.94544991  50.94985144  54.95359251  58.95681119  62.95960956  66.96206473  70.96423603  74.96616986
      78.96790302  82.96946509  86.9708801  90.97216777  94.97334447  98.97442384  102.9754174  106.9763349


I(K,K;K+2,K+1)
      0.04801737665  0.03964928145  0.03044423627  0.02443619659  0.02035069317  0.01741960881  0.01522249717  0.01351765574
      0.0121579357  0.01104910934  0.01012821187  0.009351637219  0.008688259511  0.008115281009  0.007615628933  0.007176268695
      0.006787079017  0.006440082532  0.006128907591  0.005848404223  0.005594365158  0.005363319865  0.00515238029  0.004959123756
       0.004781503006  0.004617776319  0.004466452672
I(K,K+1;K+2,K+1)
      0.3924592439  0.2128484674  0.1465890585  0.1119120552  0.0905554768  0.07607678176  0.06561478556  0.0577031181
      0.05151214579  0.04653705253  0.04245298777  0.03904140773  0.03614986694  0.03366878043  0.0315173475  0.02963468214
      0.02797403328  0.02649890784  0.0251804037  0.02399533368  0.02292487983  0.02195361086  0.02106875338  0.02025964358
      0.01951730928  0.01883414762  0.01820367366
I(K,K+1;K+2,K+2)
      0.1280463377  0.06343885032  0.04175209546  0.03103009091  0.02466750688  0.02046499496  0.01748635572  0.01526699943
      0.01355064041  0.01218448147  0.01107183409  0.01014855935  0.009370448776  0.008706048593  0.008132373499  0.00763223R846
      0.00719254088  0.006803114211  0.006455952556  0.006144466485  0.005864087812  0.005610004861  0.005378938856  0.005167996967
      0.004974753028  0.004797157198  0.004633465825
```

```
REFNO = 3
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE SUBMILLIMETER TRANSITIONS OF O16=O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2918039  23.8629875  35.3953573  46.9116331  58.4157134  69.9078008  81.3869569  92.8517942  104.300718  115.732026
      127.143957  138.534712  149.902465  161.245378  172.561598  183.849261  195.106497  206.331426  217.522165  228.676821
      239.793497  250.870291  261.905292  272.896585  283.842248  294.740355  305.58897

NUG:  14.1685942  25.8125556  37.3830984  48.9275203  60.4554768  71.9692325  83.4687716  94.9531812  106.421136  117.871099
      129.301414  140.710352  152.096142  163.456977  174.791032  186.096465  197.371419  208.61403   219.822421  230.994709
      242.129004  253.223407  264.276014  275.284913  286.248185  297.163907  308.030146

NUM:  16.2529117  27.8241494  39.3566041  50.8729957  62.3772226  73.8694876  85.3488521  96.8139287  108.263123  119.694732
      131.106995  142.498112  153.866259  165.209597  176.526272  187.814422  199.072174  210.297652  221.488969  232.644235
      243.761552  254.839017  265.874721  276.866747  287.813175  298.712077  309.561517

     THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF:  3.96108467  18.3372061  44.2117874  81.5806504  130.437759  190.775218  262.583274  345.850311  440.562853  546.705557
      664.261217  793.210755  933.533226  1085.20581  1248.20381  1422.50065  1608.06786  1804.87512  2012.89016  2232.07888
      2462.40522  2703.83127  2956.31717  3219.82117  3494.29959  3779.70683  4075.99535

ELG:  2.08429436  16.387638  42.2240463  79.5647631  128.397995  188.713786  260.501459  343.748924  438.442435  544.566485
      662.10376  791.035114  931.33955  1082.99421  1245.97437  1420.25344  1605.80294  1802.59251  2010.58991  2229.76099
      2460.06972  2701.47816  2953.94645  3217.43284  3491.89365  3777.28328  4073.55418

ELM:  2.08429436  16.387638  42.2240463  79.5647631  128.397995  188.713786  260.501459  343.748924  438.442435  544.566485
      662.10376  791.035114  931.33958  1082.99421  1245.97437  1420.25344  1605.80294  1802.59251  2010.58991  2229.76099
      2460.06972  2701.47816  2953.94645  3217.43284  3491.89365  3777.28328  4073.55418

     THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF         (GHZ)
      368.49901  715.394369  1061.12612  1406.37538  1751.25903  2095.78314  2439.91959  2783.62676  3126.85686  3469.55887
      3811.67995  4153.16617  4493.96285  4834.01484  5173.26656  5511.66219  5849.14562  6185.66054  6521.15044  6855.55862
      7188.8282  7520.90211  7851.72312  8181.23379  8509.37653  8836.09354  9161.32683
 NUG         (GHZ)
      424.763768  773.840949  1120.7171  1466.81016  1812.4096  2157.58331  2502.33082  2846.62476  3190.4254  3533.68666
      3876.35887  4218.39024  4559.72761  4900.31689  5240.10331  5579.03166  5917.0463  6254.09128  6590.11038  6925.04716
      7258.84491  7591.44676  7922.79857  8252.83406  8581.50471  8908.74982  9234.51146
 NUM         (GHZ)
      487.250035  834.147014  1179.88131  1525.13404  1870.02209  2214.55153  2558.69422  2902.40856  3245.64676  3588.3578
      3930.48883  4271.98592  4612.79441  4952.85912  5292.1245  5630.53471  5968.03364  6304.565  6640.07225  6974.49571
      7307.7875  7639.88154  7970.72361  8300.25627  8628.42192  8955.16277  9280.42081
```

```
REFNO = 3
NINPUT:  1   3   5   7   9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16=O16 ARE AS FOLLOWS:

FP:  56.2647579  58.44658  59.5909792  60.4347785  61.1505671  61.8001671  62.4112332  62.9979989  63.5685416  64.1277886
     64.6789184  65.2240747  65.7647576  66.3020493  66.8367509  67.3694694  67.9006738  68.4307328  68.959941  69.488537
     70.0167169  70.5446437  71.0724542  71.6002647  72.1281752  72.6562718  73.1846301

FM:  118.750331  62.4862673  60.306065  59.1642114  58.3238834  57.6124916  56.9682142  56.3633964  55.7838046  55.2213614
     54.6711396  54.1299608  53.595681  53.0668003  52.5422365  52.0211885  51.5030491  50.9873496  50.4737211  49.9618692
     49.451555  48.9425826  48.4347891  47.9280374  47.4222114  46.9172111  46.4129503

          THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.485573  491.289028  1265.84506  2385.29159  3849.27507  5657.49699  7809.63728  10305.3335  13144.1735  16325.6925
     19849.3714  23714.6361  27920.8573  32467.3497  37353.372  42578.1271  48140.7611  54040.364  60275.9691  66846.5528
     73751.0348  80988.2776  88557.0867  96456.2101  104684.338  113240.104  122122.082

ELM: 0  487.249341  1265.12998  2386.56216  3852.10175  5661.68466  7815.0803  10311.9681  13151.9583  16334.5989  19859.3792
     23725.7302  27933.0264  32480.5849  37367.6665  42593.4753  48157.1587  54057.8074  60294.4553  66866.0794  73771.5999
     81009.8797  88579.7244  96479.8823  104709.044  113265.843  122148.854

          THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 430.985277  775.700434  1120.29033  1464.69926  1808.87152  2152.75136  2496.28299  2839.41057  3182.07822  3524.23001
     3865.80991  4206.76185  4547.02965  4886.55707  5225.28775  5563.16524  5900.13297  6236.13426  6571.11231  6905.01018
     7237.77078  7569.3369  7899.65115  8228.656  8556.29375  8882.50649  9207.23618


          THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
          OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
     THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 3 AND THOSE OBSERVED IS:
     0.0242882435 GHZ = 24.2882435 MHZ = 0.000810168597 INVERSE CM.
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THE PARAMETERS ACCORDING TO EVENSON AND MIZUSHIMA
      (REF. 4) ARE AS FOLLOWS:

H0 = 43.100518 GHZ = 1.437678529 INVERSE CM)
B1 = -0.00014496 GHZ = -4.835345124E-6 INVERSE CM)
B2 = -1.7E-10 GHZ = -5.670589618E-12 INVERSE CM)

LAM0 = 59.501342 GHZ = 1.984751131 INVERSE CM)
LAM1 = 5.847E-5 GHZ = 1.950349265E-6 INVERSE CM)

MU0 = -0.2525865 GHZ = -0.008425378733 INVERSE CM)
MU1 = -2.464E-7 GHZ = -8.219019306E-9 INVERSE CM.

TEMP = 296   REFNO = 4   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.451982623  6.710350719  10.8028891  14.8505638  18.87964931  22.89924706  26.91334893  30.92398235  34.93228651
      38.93895089  42.94441724  46.9[illegible]317  50.9528502  54.95617044  58.95905104  62.96157373  66.96380116  70.96578214
      74.96755531  78.9691516  82.97059611  86.97190941  90.97310849  94.97420755  98.9752185  102.9761515  106.977015
I(K,K-1;K,K)
      2  6.538620329  10.73656115  14.81539076  18.8578588  22.88442234  26.90261193  30.91584698  34.92590947  38.93381776
      42.94019647  46.94544991  50.94985144  54.95359252  58.95681119  62.95960956  66.96206473  70.96423603  74.96616986
      78.96790302  82.96946509  86.9708801  90.97216778  94.97334447  98.97442384  102.9754174  106.9763349

I(K,K;K+2,K+1)
      0.04801737656  0.03964928123  0.03044423592  0.02443619611  0.02035069257  0.01741960807  0.01522249963  0.01351765475
      0.01215793458  0.01104910806  0.01012821049  0.009351635705  0.008688257864  0.008115279229  0.007615627019  0.007176266644
      0.006787076683  0.006440080208  0.006128905127  0.005848401619  0.005594362411  0.005363316976  0.005152377255  0.004959120575
      0.004781499676  0.004617772839  0.004466449039
I(K,K+1;K+2,K+1)
      0.3924592432  0.2128484662  0.1465890568  0.111912093  0.0905554738  0.07607677856  0.06561478184  0.05770311387
      0.05151214104  0.04653704725  0.04245298197  0.03904140141  0.03614986009  0.03366877304  0.03151733957  0.02963467367
      0.02797402427  0.02649889828  0.02518039358  0.023995323  0.02292486858  0.02195359903  0.02106874097  0.02025963058
      0.01951729569  0.01883413342  0.01820365885
I(K,K+1;K+2,K+2)
      0.1280463375  0.06343884996  0.04175209498  0.0310300903  0.02466750614  0.02046499541  0.01748635473  0.01526659831
      0.01355063916  0.01218448009  0.01107183258  0.01014985577  0.009370447  0.008706046683  0.008132371455  0.007632235666
      0.007192538563  0.006803111756  0.006455949961  0.006144662114  0.005864084933  0.005610001839  0.005378935688
      0.005167993651  0.004974749563  0.004797153582  0.004633462056
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REFNO = 4
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

         THE SUBMILLIMETER TRANSITIONS OF O16=O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2918039   23.8629876   35.3953574   46.9116333   58.4157136   69.9078007   81.3869559   92.8517913   104.300711   115.732014
      127.143936   138.534677   149.902411   161.245298   172.561482   183.849099   195.106274   206.331126   217.521768   228.676304
      239.792834   250.86945    261.904237   272.895275   283.840637   294.738389   305.586591

NUG:  14.1685942   25.8125557   37.3830985   48.9275206   60.455477    71.9692324   83.4687706   94.9531783   106.42113    117.871087
      129.301393   140.710318   152.096088   163.456897   174.790916   186.096302   197.371196   208.61373    219.822024   230.994193
      242.12834    253.222566   264.274959   275.283603   286.246574   297.161942   308.027767

NUM:  16.2529117   27.8241495   39.3566042   50.8729959   62.3772229   73.8694875   85.3488511   96.8134257   108.263116   119.69472
      131.106974   142.498077   153.866206   165.209517   176.526156   187.814259   199.071951   210.297352   221.488573   232.643719
      243.760889   254.838176   265.873666   276.865438   287.811564   298.710111   309.559138

     THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF:  3.96108467   18.3372061   44.2117875   81.5806506   130.437759   190.775219   262.583275   345.850311   440.56285    546.705548
      664.261195   793.210712   933.533148   1085.20568   1248.2036    1422.50032   1608.06737   1804.8744    2012.88915   2232.07747
      2462.4033    2703.82868   2956.31374   3219.81668   3494.29379   3779.69942   4075.98598

ELG:  2.08429436   16.387638    42.2240464   79.5647634   128.397996   188.713787   260.50146    343.748924   438.442431   544.566475
      662.103738   791.035071   931.339472   1082.99408   1248.97416   1420.25311   1605.80245   1802.5918    2010.58889   2229.75958
      2460.06779   2701.47556   2953.94302   3217.42836   3491.88786   3777.27587   4073.5448

ELM:  2.08429436   16.387638    42.2240464   79.5647634   128.397996   188.713787   260.50146    343.748924   438.442431   544.566475
      662.103738   791.035071   931.339472   1082.99408   1248.97416   1420.25311   1605.80245   1802.5918    2010.58889   2229.75958
      2460.06779   2701.47556   2953.94302   3217.42836   3491.88786   3777.27587   4073.5448

     THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF          (GHZ)
      368.49901    715.394371   1061.12612   1406.37539   1751.25904   2095.78314   2439.91956   2783.62667   3126.85667   3469.5585
      3811.67931   4153.16813   4493.96124   4834.01243   5173.26309   5511.65732   5849.13893   6185.65154   6521.13855   6855.54314
      7188.80832   7520.8769    7851.69149   8181.19453   8509.32823   8836.03462   9161.25551
NUG          (GHZ)
      424.763768   773.840951   1120.7171    1466.81017   1812.4096    2157.58331   2502.33079   2846.62467   3190.42521   3533.68629
      3876.35823   4218.3892    4559.726     4900.31448   5240.09984   5579.02679   5917.03961   6254.08228   6590.09849   6925.03168
      7258.82503   7591.42154   7922.76395   8252.7948    8581.45641   8908.6909    9234.44014
NUM          (GHZ)
      487.250035   834.147016   1179.88131   1525.13405   1870.0221    2214.55152   2558.69419   2902.40848   3245.64657   3588.35743
      3930.48819   4271.98488   4612.7928    4952.85672   5292.12103   5630.52984   5968.02696   6304.556     6640.06036   6974.48323
      7307.76762   7639.85633   7970.69198   8300.217     8628.37362   8955.10384   9280.34949
```

```
REFNO = 4
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
      O16=O16 ARE AS FOLLOWS:

FP:   56.2647579  58.44658  59.5909792  60.4347784  61.1505671  61.8001671  62.4112332  62.9979989  63.5685417  64.1277887
      64.6789185  65.2240749  65.7647579  66.3020496  66.8367513  67.36947  67.9006745  68.4307336  68.9599419  69.4885381
      70.0167183  70.5446452  71.072456  71.6002668  72.1281775  72.6562745  73.1846331

FM:   118.750331  62.4862673  60.306068  59.1642114  58.3238834  57.6124916  56.9682142  56.3633964  55.7838045  55.2213613
      54.6711395  54.1299606  53.5956808  53.0668  52.5422362  52.021188  51.5030486  50.9873489  50.4737203  49.9618682
      49.4515539  48.9425813  48.4347875  47.9280356  47.4222093  46.9172088  46.412947

          THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
      RELATIVE TO THE GROUND STATE) ARE:

ELP:  62.485573  491.289028  1265.84507  2385.2916  3849.27608  5657.49701  7809.6373  10305.3335  13144.1734  16325.6922
      19849.3707  23714.6348  27920.8549  32467.3457  37353.3687  42578.1172  48140.7464  54040.3426  60275.9387  66846.5105
      73750.977  80988.2  88556.9638  96456.0756  104684.164  113239.882  122121.801

ELM:  0  487.249341  1265.12998  2386.56217  3852.10176  5661.68468  7815.08032  10311.9681  13151.9582  16334.5986  19859.3785
      23725.7289  27933.024  32480.5809  37367.6602  42593.4655  48157.144  54057.786  60294.4249  66866.0372  73771.5422
      81009.802  88579.6215  96479.7478  104708.87  113265.621  122148.573

          THE PREDICTED LMR AND RAMAN LINES CONNECTING
      STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL:  430.985278  775.700436  1120.29033  1464.69927  1808.87153  2152.75136  2496.28295  2839.41048  3182.07803  3524.22964
      3865.80927  4206.76081  4547.02804  4886.55467  5225.28428  5563.16037  5900.12628  6236.12527  6571.10042  6904.99469
      7237.7509  7569.31168  7899.61953  8228.61674  8556.24544  8882.44757  9207.16486

          THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
      OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
    THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 4 AND THOSE OBSERVED IS:
    0.0242705979 GHZ = 24.2705979 MHZ = 0.000809580003 INVERSE CM.
```

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THE PARAMETERS ACCORDING TO ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE
      (REF. 5) ARE AS FOLLOWS:

B0 = 43.10140152 GHZ = 1.437708 INVERSE CM,
B1 = -0.0001450995497 GHZ = -4.84E-6 INVERSE CM,
B2 = -1.13921134E-12 GHZ = -3.8E-14 INVERSE CM,

LAM0 = 59.53428527 GHZ = 1.98585 INVERSE CM,
LAM1 = 0 GHZ = 0 INVERSE CM,

MU0 = -0.2529049176 GHZ = -0.008436 INVERSE CM,
MU1 = 0 GHZ = 0 INVERSE CM.

TEMP = 296   REFNO = 5   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.451932553  6.710310398  10.80245943  14.85054142  18.87963217  22.89923395  26.91333908  30.92397523  34.93228177
      38.93894826  42.94441652  46.94898274  50.9528529  54.95617469  58.95905678  62.9615809  66.9638097  70.96579202  74.96756649
      78.96916407  82.97060984  86.97192438  90.97312469  94.97422496  98.97523712  102.9761713  106.9770361
I(K,K-1;K,K)
      2  6.538486807  10.73649664  14.81535008  18.85783037  22.88440263  26.90259653  30.91583566  34.92590143  38.93381249
      42.94019357  46.94544912  50.94985258  54.95359542  58.95681576  62.95961569  66.96207235  70.96424509  74.9661803
      78.96791481  82.96947819  86.97089449  90.97218343  94.97336138  98.97444199  102.9754368  106.9763555

I(K,K;K+2,K+1)
      0.04806744729  0.03968964016  0.03047389973  0.02445858019  0.02036782853  0.01743271534  0.01523234938  0.01352477219
      0.01216267896  0.01105174?2  0.01012892962  0.00935088927  0.008685561831  0.008111025123  0.007609887972  0.007169101666
      0.006778533884  0.006430198475  0.006117716704  0.005835932799  0.005580634682  0.005348347788  0.005136180639
      0.004941707621  0.004762878929  0.00459795061  0.004445429668
I(K,K+1;K+2,K+1)
      0.3928604624  0.213063637  0.1467314882  0.112014398  0.09063164229  0.07613397845  0.06565722833  0.05773348292
      0.05153223556  0.04654813775  0.04245999555  0.03903703361  0.03613864443  0.03365112616  0.03149359154  0.02960508898
      0.02793881671  0.02645824176  0.02513443009  0.02394416864  0.02286861816  0.02189232961  0.02100251464  0.02018849666
      0.01944129252  0.01875328972  0.01811799492
I(K,K+1;K+2,K+2)
      0.1281798894  0.06380336255  0.04179277678  0.03108851453  0.02468827701  0.02048039285  0.01749767313  0.01527503682
      0.01355592701  0.01218738467  0.01107261872  0.01014742209  0.009367539279  0.008701482891  0.008126242995  0.007624616434
      0.007183485259  0.006792672984  0.006444164511  0.006131561666  0.005849695344  0.005594344147  0.00536202688  0.005149847282
      0.004955376236  0.004776561344  0.004611656712
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```
REFNO = 5
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53


          THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2911194   23.8625455   35.3951905   46.9117578   58.4161417   69.9085442   81.3880281   92.853269   104.302497   115.734198
      127.146558   138.537789   149.906084   161.249618   172.566559   183.855069   195.113304   206.339416   217.531557   228.687875
      239.806518   250.885631   261.92336    272.917849   283.867242   294.769683   305.623314

NUG:  14.1691004   25.81327     37.3840592   48.9287333   60.4569396   71.9709405   83.4707204   94.9553689   106.423565   117.873778
      129.30436    140.713598   152.099724   163.460958   174.795492   186.101508   197.377175   208.62066    219.830123   231.003719
      242.139602   253.235924   264.290833   275.302478   286.269005   297.188561   308.05929

NUM)  16.2543834   27.8258095   39.3584545   50.8750218   62.3794057   73.8718082   85.3512921   96.816473   108.265761   119.697462
      131.109822   142.501053   153.869348   165.212882   176.529823   187.818333   199.076568   210.30268    221.494821   232.651139
      243.769782   254.848895   265.886624   276.881113   287.830506   298.732947   309.586578


        THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELFI  3.963264     18.3396664   44.2147514   81.5843371   130.442383   190.780991   262.590403   345.859003   440.573316   546.718009
      664.275891   793.22791    933.553157   1085.22886   1248.23041   1422.5313    1608.10319   1804.91569   2012.93732   2232.13358
      2462.46887   2703.90587   2956.40417   3219.92332   3494.41981   3779.84855   4076.16262

ELG:  2.08528301   16.3889419   42.2258826   79.5673616   128.401585   188.712595   260.507711   343.756843   438.452248   544.578429
      662.118088   791.052104   931.359517   1083.01752   1246.00147   1420.28486   1605.83932   1802.63464   2010.63876   2229.81774
      2460.13579   2701.55828   2954.0367    3217.5387    3492.01805   3777.42967   4073.72664

ELM:  2.08528301   16.3889419   42.2258826   79.5673616   128.401585   188.718595   260.507711   343.756843   438.452248   544.578429
      662.118088   791.052104   931.359517   1083.01752   1246.00147   1420.28486   1605.83932   1802.63464   2010.63876   2229.81774
      2460.13579   2701.55828   2954.0367    3217.5387    3492.01805   3777.42967   4073.72664

          THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF          (GHZ)
      368.478489   715.381116   1061.12112   1406.37912   1751.27187   2095.80543   2439.9517    2783.66918   3126.9102    3469.62396
      3811.75791   4153.25844   4494.07133   4834.14193   5173.4153    5511.83631   5849.34969   6185.90007   6521.43202   6855.89002
      7189.21854   7521.362     7852.26479   8181.87127   8510.12582   8836.97277   9162.35644
NUG          (GHZ)
      424.778943   773.862365   1120.7459    1466.84652   1812.45345   2157.63452   2502.38924   2846.69034   3190.49822   3533.76697
      3876.4472    4218.48747   4559.83501   4900.43625   5240.23703   5579.18284   5917.21885   6254.29005   6590.34128   6925.31727
      7259.16265   7591.82201   7923.23985   8253.36066   8582.12887   8909.48891   9235.38517
NUM          (GHZ)
      487.294155   834.196781   1179.93678   1525.19478   1870.08754   2214.62109   2558.76737   2902.48484   3245.72587   3588.43963
      3930.57357   4272.07411   4612.887     4952.9576    5292.23096   5630.65197   5968.16535   6304.71574   6640.24768   6974.70569
      7308.03421   7640.17766   7971.08045   8300.68694   8628.94149   8955.78843   9281.17211
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REFNO = 5
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53


           THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16-O16 ARE AS FOLLOWS:

FP:  56.3004538  58.4812494  59.624788  60.4674059  61.1815823  61.8290861  62.4375431  63.0211663  63.5880162  64.1430052
     64.689298  65.2290252  65.7636742  66.2943144  66.8217349  67.3465303  67.8691575  68.3899731  68.9092597  69.4272439
     69.9441099  70.4600086  70.975065  71.4893835  72.0030519  72.5161448  73.0287257

FM:  118.815666  62.5152118  60.3344162  59.1908806  58.3482598  57.6340833  56.9865795  56.3781226  55.7944994  55.2276494
     54.6726604  54.1263676  53.5866404  53.0519914  52.5213512  51.9939307  51.4691353  50.9465081  50.4256925  49.9064059
     49.3884217  48.8715557  48.355657  47.8406007  47.3262822  46.8126137  46.2995208

        THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.5152118  491.328118  1265.90011  2385.36949  3849.38269  5657.64114  7809.82469  10305.5709  13144.4677  16326.0506
     19849.8009  23715.1455  27921.4559  32468.0486  37354.1844  42579.0689  48141.8517  54041.6271  60277.4335  66848.254
     73753.0156  80990.3898  88559.7924  96489.3834  104688.067  113244.493  122127.252

ELM: 0  487.294155  1265.19048  2386.64602  3852.21601  5661.[illegible]3614  7815.27566  10312.2139  13152.2612  16334.9659  19859.8175
     23726.2481  27933.6329  32481.2909  37368.4848  42594.4215  48158.2517  54059.0705  60295.9171  66867.7748  73773.5712
     81012.1782  88582.4118  96483.0322  104712.744  113270.196  122153.982

        THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 430.993701  775.715832  1120.312  1464.72738  1808.90595  2152.79201  2496.32982  2839.46366  3182.13785  3524.29662
     3865.88427  4206.84508  4547.12333  4885.66328  5225.40923  5563.30544  5900.2962  6236.32577  6571.33842  6905.27845
     7238.0901  7569.71766  7900.10539  8229.19756  8556.93844  8883.27229  9208.14338


        THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
        OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
    THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 5 AND THOSE OBSERVED IS:
    0.0578997886 GHZ = 57.8997886 MHZ = 0.00193132896 INVERSE CM.
```

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THE PARAMETERS ACCORDING TO TOMUTA, MIZUSHIMA, HOWARD, AND EVENSON
      (REF. 6) ARE AS FOLLOWS:

B0 = 43.1004608 GHZ = 1.437676621 INVERSE CM;
B1 = -0.0001452 GHZ = -4.843350662E-6 INVERSE CM;
H2 = 0 GHZ = 0 INVERSE CM;

LAM0 = 59.501342 GHZ = 1.984751131 INVERSE CM;
LAM1 = 5.847E-5 GHZ = 1.950349265E-6 INVERSE CM;

MU0 = -0.2525865 GHZ = -0.008425378733 INVERSE CM;
MU1 = -2.464E-7 GHZ = -8.219019306E-9 INVERSE CM.

TEMP = 296   REFNO = 6   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.451982489  6.710350595  10.60288899  14.8505637  18.879642  22.8992495  26.9133482  30.92398223  34.93228638
     38.93895076  42.9444171  46.94898155  50.95285004  54.95617027  58.95905086  62.96157354  66.96380096  70.96578193
     74.96755509  78.96915137  82.97059587  86.97190916  90.97310823  94.97420727  98.97521821  102.9761512  106.9770147
I(K,K-1;K,K)
      2  6.538619971  10.73656095  14.81539061  18.85785867  22.88442328  26.9026118  30.9158465  34.92590934  38.93381764
     42.94019633  46.94544975  50.94985128  54.95359234  58.95681101  62.95960937  66.96206453  70.96423582  74.96616964
     78.96790279  82.96946485  86.97087985  90.97216751  94.97334419  98.97442355  102.9754171  106.976346


I(K,K;K+2,K+1)
      0.04801751085  0.03964949046  0.03044434557  0.02443630043  0.02035079666  0.01741971502  0.01522260807  0.0135177727
      0.01215805965  0.01104924101  0.01012835181  0.009351785876  0.008688417254  0.008115448152  0.007615805751  0.007176455433
      0.006787275904  0.006440289778  0.006129125397  0.005844863278  0.005594604663  0.005363570502  0.005152642246
      0.004959397219  0.004781788165  0.004618073367  0.004466761805
I(K,K+1;K+2,K+1)
      0.3924603193  0.2128491246  0.1465895832  0.11191253  0.09055593649  0.07607724526  0.06561526335  0.05770361711
      0.05151267078  0.04653760694  0.0424535742  0.03904202823  0.03615052316  0.0336694 7377  0.03151807916  0.029635 4532
      0.02797488447  0.02649976052  0.02518129848  0.02399627137  0.02292586122  0.02195463672  0.02106982449  0.0202607607
      0.01951844732  0.01883535911  0.01820493352
I(K,K+1;K+2,K+2)
      0.1280466956  0.06343904736  0.04175224535  0.03103022277  0.02466763232  0.02046511974  0.01748648312  0.01526713151
      0.01355077856  0.01218462667  0.01107198707  0.01014872067  0.009370618905  0.008706227903  0.008132562315  0.007632437 45
      0.007192749529  0.006803333314  0.006456181985  0.006144904989  0.005864338864  0.005610267026  0.005379212 33  0.005168281948
      0.004975049711  0.004797465784  0.004633786518
```

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REFNO = 6
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2917841  23.8629476  35.395291  46.911532  58.4195675  69.9076009  81.3866937  92.8514611  104.300313  115.731553
      127.143428  138.53415  149.901909  161.244881  172.561232  183.849124  195.106712  206.332149  217.523584  228.679166
      239.797041  250.875355  261.912253  272.905878  283.854375  294.755886  305.608553

NUG:  14.1685748  25.8125159  37.3830322  48.9274194  60.4553314  71.9690328  83.4685085  94.9528483  106.420731  117.870626
      129.300885  140.709791  152.095585  163.456479  174.790667  186.096328  197.371635  208.614753  219.82384  230.997054
      242.132547  253.228471  264.282974  275.294206  286.260311  297.179437  308.049729

NUM:  16.2528919  27.8241094  39.3565377  50.8728946  62.3770771  73.8692877  85.3485889  96.8135956  108.262717  119.694259
      131.106466  142.497551  153.865703  165.209099  176.525907  187.814285  199.07239  210.298375  221.490389  232.64658
      243.765096  254.844082  265.881682  276.876041  287.825302  298.727607  309.581101

          THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF:  3.96108467  18.3371859  44.211727  81.5805235  130.437531  190.774844  262.5827  345.849474  440.561683  546.703982
      664.259167  793.208177  933.530087  1085.20211  1248.19961  1422.49609  1608.06317  1804.87064  2012.88641  2232.07654
      2462.40523  2703.83482  2956.32579  3219.83675  3494.32446  3779.74383  4076.04788

ELG:  2.08429397  16.3876176  42.2239858  79.5646361  128.397767  188.713412  260.500885  343.748087  438.441264  544.564909
      662.101711  791.032536  931.33641  1082.99052  1245.97018  1420.24888  1605.79825  1802.58803  2010.58615  2229.75865
      2460.06973  2701.48171  2953.95507  3217.44842  3491.91853  3777.32028  4073.60671

ELM:  2.08429397  16.3876176  42.2239858  79.5646361  128.397767  188.713412  260.500885  343.748087  438.441264  544.564909
      662.101711  791.032536  931.33641  1082.99052  1245.97018  1420.24888  1605.79825  1802.58803  2010.58615  2229.75865
      2460.06973  2701.48171  2953.95507  3217.44842  3491.91853  3777.32028  4073.60671

          THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF        (GHZ)
      368.498417  715.393171  1061.12413  1406.37235  1751.25467  2095.77715  2439.91169  2783.61677  3126.84471  3469.54468
      3811.66409  4153.14935  4493.94618  4833.99992  5173.2556  5511.65809  5849.15209  6185.68221  6521.193  6855.62893
      7188.93444  7521.05394  7851.93181  8181.51241  8509.74008  8836.55915  9161.91394
 NUG        (GHZ)
      424.763186  773.839758  1120.71511  1466.80713  1812.40524  2157.57732  2502.32293  2846.61478  3190.41326  3533.67247
      3876.34302  4218.37342  4559.71094  4900.30197  5240.09236  5579.02756  5917.05276  6254.11294  6590.15294  6925.11746
      7258.95115  7591.59857  7923.00425  8253.11266  8581.86823  8909.2154  9235.09854
 NUM        (GHZ)
      487.249442  834.145816  1179.87932  1525.13101  1870.01773  2214.54553  2558.68632  2902.39856  3245.63461  3588.34361
      3930.47297  4271.9691  4612.77774  4952.8442  5292.11354  5630.53061  5968.04011  6304.58667  6640.11481  6974.55902
      7307.89374  7640.03337  7970.9323  8300.53488  8628.78546  8955.62837  9281.00792
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REFNO = 6
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

         THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
    O16-O16 ARE AS FOLLOWS:

FP:  56.2647695  58.4465871  59.5909848  60.4347834  61.1505718  61.8001717  62.4112376  62.9980032  63.5685458  64.1277927
     64.6789221  65.2240781  65.7647605  66.3020515  66.8367523  67.3694699  67.9006732  68.4307308  68.9599375  69.4885318
     70.0167097  70.5446343  71.0724424  71.6002502  72.1281576  72.6562509  73.1846056

FM:  118.750331  62.4862556  60.306058  59.1642058  58.3238784  57.6124869  56.9682096  56.3633919  55.7838002  55.2213572
     54.6711356  54.129957  53.5956776  53.0667974  52.5422343  52.021187  51.5030486  50.9873502  50.4737231  49.9618727
     49.4515602  48.9425898  48.4347984  47.9280492  47.4222259  46.9172287  46.4129712

         THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
    RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4855614  491.288416  1265.84325  2385.28778  3849.26822  5657.48578  7809.62007  10305.3084  13144.1384  16325.6452
     19849.3099  23714.5588  27920.7632  32467.2389  37353.2463  42577.9904  48140.6203  54040.2297  60275.8564  66846.4827
     73751.035  80988.3841  88557.345  96456.6771  104685.084  113241.213  122123.657

ELM: 0  487.248748  1265.12817  2386.85836  3852.09492  5661.67346  7815.0631  10311.943  13151.9232  16334.5517  19859.3177
     23725.6529  27932.9323  32480.4741  37367.5408  42593.3387  48157.0179  54057.6731  60294.3426  66866.0094  73771.6002
     81009.9862  88579.9827  96480.3493  104709.79  113266.952  122150.428

         THE PREDICTED LMR AND RAMAN LINES CONNECTING
    STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 430.984672  775.699229  1120.28833  1464.69623  1808.86716  2152.74536  2496.27509  2839.40057  3182.06607  3524.21581
     3865.79405  4206.74502  4547.01298  4886.54215  5225.27679  5563.16114  5900.13944  6236.15594  6571.15487  6905.08049
     7237.87703  7569.48874  7899.85986  8228.93463  8556.6573  8882.97212  9207.82331


         THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
         OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
     THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 6 AND THOSE OBSERVED IS:
     0.0237967896 GHZ = 23.7967896 MHZ = 0.00079377546 INVERSE CM.
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THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR O16-O16:

B0 = 43.10046 GHZ = 1.437676594 INVERSE CM,
B1 = -0.00014501 GHZ = -4.837012944E-6 INVERSE CM,
B2 = 0 GHZ = 0 INVERSE CM,

LAM0 = 59.501341 GHZ = 1.984751097 INVERSE CM,
LAM1 = 5.848E-5 GHZ = 1.950682829E-6 INVERSE CM,

MU0 = -0.252586 GHZ = -0.008425362055 INVERSE CM,
MU1 = -2.47E-7 GHZ = -8.239033151E-9 INVERSE CM.

TEMP = 296   REFNO = 7   ISOTOPE = 66
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.451982494  6.710350609  10.80288901  14.85056373  18.87964924  22.899247  26.91334868  30.92398229  34.93228646
      38.93895084  42.94441719  46.94898164  50.95285015  54.95617038  58.95905098  62.96157368  66.9638011  70.96578205
      74.96755524  78.96915153  82.97059605  86.97190934  90.97310842  94.97420747  98.97521843  102.9761514  106.977015
I(K,K-1;K,K)
      2  6.538619985  10.73656097  14.81539064  18.8578587  22.88442332  26.90261186  30.91584691  34.92590941  38.93381772
      42.94019641  46.94544985  50.94985138  54.95359246  58.95681114  62.9596095  66.96206467  70.96423597  74.9661698
      78.96790296  82.96946503  86.97088003  90.97216771  94.9733444  98.97442377  102.9754173  106.9763348


I(K,K;K+2,K+1)
      0.04801750578  0.03964939083  0.03044432343  0.02443627  0.02035075795  0.01741966803  0.01522255279  0.01351770909
      0.0121579877  0.01104916066  0.01012826303  0.009351688615  0.008688311458  0.008115333765  0.00761568271  0.007176323669
      0.006787135344  0.006440140344  0.006128967005  0.005848465345  0.005594428082  0.00536338466  0.005152447077  0.004959192592
       0.004781573962  0.004617849466  0.004466528076
I(K,K+1;K+2,K+1)
      0.3924602786  0.2128490511  0.146589477  0.1119123908  0.09055576444  0.07607704021  0.06561502519  0.05770334572
      0.05151236б  0.04653726862  0.04245320216  0.03904162226  0.03615008305  0.03366899927  0.03151757002  0.02963490913
      0.02797426541  0.0264991457  0.02518064778  0.02399558444  0.02292513767  0.02195387615  0.02106902646  0.0202599247F
      0.0195175989  0.01883444594  0.01820398096
I(K,K+1;K+2,K+2)
      0.1280466821  0.06343902523  0.04175221499  0.03103018413  0.02466758 54  0.02046506454  0.01748641962  0.01526705968
      0.01355069836  0.01218453807  0.01107189002  0.01014861512  0.009370504803  0.008706105189  0.008132430925  0.007632297314
      0.007192600572  0.006803175282  0.006456015 14  0.006144729068  0.00586415377  0.005610072657  0.00537900858  0.005164068702
      0.004974826852  0.004797233185  0.004633544048
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```
REFNO = 7
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

            THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
      FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.2917847  23.8629518  35.3953043  46.9115624  58.4156257  69.9076988  81.3868469  92.8516874  104.300632  115.731988
      127.144004  138.534894  149.90285  161.246052  172.562669  183.850862  195.108792  206.334612  217.526475  228.682531
      239.80093  250.87982  261.917348  272.91166  283.860902  294.76322  305.616758

NUG:  14.1685753  25.81252  37.3830454  48.9274496  60.455389  71.9691304  83.4686615  94.9530743  106.42105  117.871061  129.30146
       140.710535  152.096527  163.457651  174.792103  186.098066  197.373715  208.617216  219.826731  231.00042  242.136438
      253.232937  264.288071  275.299989  286.26684  297.186774  308.057937

NUH:  16.2528925  27.8241136  39.3565511  50.872925  62.3771349  73.8693856  85.3487422  96.8138219  108.263037  119.694694
      131.107042  142.498295  153.866645  165.210271  176.527343  187.816023  199.07447  210.300838  221.49328  232.649947
      243.768987  254.848548  265.826778  276.881824  287.83183  298.734943  309.589308

         THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
      CM) ARE AS FOLLOWS:

ELF:  3.96108462  18.3371865  44.2117319  81.5805419  130.43758  190.774951  262.582905  345.849833  440.562268  546.704887
      664.260508  793.210093  933.532747  1085.20572  1248.20439  1422.5023  1608.07112  1804.88066  2012.8989  2232.09192
      2462.42398  2703.85746  2956.35289  3219.86895  3494.36244  3779.78833  4076.09972

ELG:  2.084294  16.3876183  42.2239908  79.5646547  128.397816  188.71352  260.501091  343.748446  438.44185  544.565814
      662.103051  791.034452  931.339071  1082.99412  1245.97495  1420.25509  1605.80619  1802.59805  2010.59864  2229.77403
      2460.08847  2701.50434  2953.98217  3217.48062  3491.9565  3777.36478  4073.65854

ELM:  2.084294  16.3876183  42.2239908  79.5646547  128.397816  188.71352  260.501091  343.748446  438.44185  544.565814
      662.103051  791.034452  931.339071  1082.99412  1245.97495  1420.25509  1605.80619  1802.59806  2010.59864  2229.77403
      2460.08847  2701.50434  2953.98217  3217.48062  3491.9565  3777.36478  4073.65854

           THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF          (GHZ)
      368.498434  715.393298  1061.12453  1406.37326  1751.2564  2095.78009  2439.91629  2783.62356  3126.85429  3469.55772
      3811.68135  4153.17164  4493.9744  4834.03503  5173.29866  5511.71019  5849.21443  6185.75605  6521.27966  6855.72982
      7189.05104  7521.1878  7852.08455  8181.68573  8509.93575  8836.77902  9162.15992
 NUG          (GHZ)
      424.763201  773.339882  1120.71551  1466.80804  1812.40697  2157.58025  2502.32752  2846.62155  3190.42283  3533.68551
      3876.36027  4218.39571  4559.73916  4900.33708  5240.13541  5579.07967  5917.11511  6254.18679  6590.23961  6925.21837
      7259.06778  7591.73247  7923.15704  8253.28603  8582.06397  8909.43534  9235.3446
 NUH          (GHZ)
      487.249458  834.145942  1179.87972  1525.13192  1870.01946  2214.54847  2558.69092  2902.40537  3245.64419  3588.35665
      3930.49024  4271.9914  4612.80597  4952.87933  5292.15661  5630.58273  5968.10247  6304.66052  6640.20149  6974.66994
      7308.01037  7640.16726  7971.08508  8300.70825  8628.98118  8955.84828  9281.25395
```

```
REFNO = 7
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53


          THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16-O16 ARE AS FOLLOWS:

FP:  56.2647671  58.4465835  59.5909801  60.4347778  61.1505654  61.8001648  62.4112304  62.997996  63.5685389  64.1277864
     64.6789168  65.2240741  65.7647584  66.3020516  66.8367551  67.369476  67.900683  68.430745  68.9599866  69.4885564
     70.0167406  70.544672  71.0724876  71.6003038  72.1282203  72.6563234  73.1846888

FM:  118.750329  62.4862566  60.3060604  59.1642098  58.3238838  57.6124937  56.9682178  56.3634013  55.7838106  55.2213685
     54.6711476  54.1299695  53.5956903  53.06681  52.5422465  52.0211985  51.503059  50.9873591  50.4737301  49.9618773
     49.451562  48.9425882  48.4347929  47.9280392  47.4222108  46.9172079  46.4129441


          THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4855623  491.288437  1265.8434  2385.28834  3849.2697  5657.48899  7809.62623  10305.3192  13144.156  16325.6724
     19849.3501  23714.6163  27920.8429  32467.3468  37383.3894  42578.1766  48140.8586  54040.5303  60276.2309  66846.9438
     73751.597  80989.0627  88558.1575  96457.6423  104686.222  113242.547  122125.211

ELM: 0  487.248764  1265.12832  2386.55891  3852.09638  5661.67666  7815.06924  10311.9537  13151.9407  16334.5788  19859.3579
     23725.7104  27933.012  32480.5821  37367.6839  42593.5248  48157.2562  54057.9737  60294.7171  6[illegible]6.4705  73772.1622
     81010.6648  88580.7952  96481.3148  104710.928  113268.286  122151.982


          THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 430.984691  775.699359  1120.28874  1464.69714  1808.86889  2152.7483  2496.27969  2839.40737  3182.07566  3524.22887
     3865.81132  4206.76733  4547.04121  4886.57728  5225.31985  5563.21325  5900.20179  6236.22978  6571.24153  6905.18138
     7237.99363  7569.62259  7900.01259  8229.10794  8556.85296  8883.19196  9208.06926



        THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
        OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697  775.6975  1120.3  1464.63  1808.84  2152.77  2496.283  2839.4006  3182.07  3524.221  3865.81
    THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 7 AND THOSE OBSERVED IS:
    0.023542255 GHZ = 23.542255 MHZ = 0.000785285099 INVERSE CM.
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THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR O16-O18:

B0 = 40.707406 GHZ = 1.357852972 INVERSE CM;
B1 = -0.000129 GHZ = -4.302976828E-6 INVERSE CM;
B2 = 0 GHZ = 0 INVERSE CM;

LAM0 = 59.499097 GHZ = 1.984676246 INVERSE CM;
LAM1 = 5.312E-5 GHZ = 1.771892474E-6 INVERSE CM;

MU0 = -0.238488 GHZ = -0.007955103394 INVERSE CM;
MU1 = -6.19E-7 GHZ = -2.064761749E-8 INVERSE CM.

TEMP = 296   REFNO = 7   ISOTOPE = 68
K = 0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33
     34  35  36  37  38  39

I(K,K+1;K,K)
     0  2.446198334  4.615752304  6.705561725  8.761263232  10.79921037  12.82673301  14.84761116  16.86399319  18.8771908[illegible]
     20.88805071  22.89714345  24.90486797  26.91151147  28.91728599  30.92235153  32.92683105  34.93082063  36.93439644
     38.93761962  40.94053985  42.94319787  44.94562744  46.94785676  48.94990958  50.95180602  52.95356228  54.95519609
     56.95671719  58.95813766  60.95946712  62.96071403  64.96188582  66.96298907  68.96402959  70.96501257  72.96594263
     74.96682392  76.96766016  78.9684547
I(K,K-1;K,K)
     0  2  4.224386818  6.523195558  8.654535571  10.72889876  12.77684221  14.81034565  16.83508707  18.85410941  20.86919157
     22.88144349  24.89159376  26.90014055  28.90743603  30.91373625  32.91923182  34.92406761  36.92835566  38.93218399
     40.93562272  42.93872841  44.94154715  46.94411692  48.94646927  50.94863064  52.95062334  54.95246635  56.95417589
     58.95576592  60.95724852  62.9586342  64.95993215  66.9611504  68.96229607  70.96337543  72.96439405  74.96535691
     76.96626844  78.96713262

I(K,K;K+2,K+1)
     0  0.05380166567  0.05091436228  0.04443827522  0.03873676759  0.03412296277  0.03040984941  0.02738883993  0.02489570295
     0.02280912326  0.02104019776  0.01952321971  0.01820895648  0.01705996352  0.01604734018  0.01514846881  0.01434541979
     0.01362381097  0.01297198005  0.01238037594  0.01184110501  0.01134758[illegible]  0.01089430205  0.01047657189  0.01009041947
     0.009732436558  0.009399687109  0.009089623449  0.008800047735  0.008529010289  0.00827481733  0.008035971163  0.007811146348
     0.007599165675  0.007398980046  0.007202[illegible]51539  0.007030339091  0.006860286326  0.006698811181  0.00654529700[illegible]
I(K,K+1;K+2,K+1)
     0.7761977944  0.4386984831  0.3084481116  0.238386878  0.1944381872  0.1642461838  0.1422090174  0.1254095305  0.112176257[illegible]
     0.10148[illegible]657  0.09265887135  0.085256064  0.07895613672  0.07352994791  0.06880777085  0.06466119596  0.0609912722
     0.05772051315  0.05478737348  0.05214234834  0.04974516501  0.04756272596  0.04556757849  0.04373676019  0.04205091671
     0.04049361972  0.03905083396  0.0377104968  0.03646218331  0.03529683747  0.03420655[illegible]6  0.03318440398  0.0322242833[illegible]
     0.03132079868  0.03046916438  0.02966511982  0.02890485928  0.02818497283  0.02750239621  0.026854[illegible]
I(K,K+1;K+2,K+2)
     0.2756131817  0.1434711084  0.09546442927  0.07110124036  0.0564911194  0.0467972060[illegible]  0.03991292735  0.034[illegible]
     0.0308084324  0.02764742213  0.02507290234  0.02293637001  0.02113539592  0.0195970863  0.01826817[illegible]  0.017[illegible]
     0.01608878678  0.01518443328  0.01437727789  0.0136525449  0.01299830391  0.01240481746  0.01186406  0.01136[illegible]
     0.01091511721  0.01049661306  0.01010982831  0.00975132554  0.009418146326  0.009107730676  0.008817852217  [illegible]
     0.008292163633  0.008053141807  0.007828169248  0.007616064328  0.00741577434[illegible]  0.00722635[illegible]31  0.00704697[illegible]
     0.006876859892
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```
REFNO = 7
NINPUT:  0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32
        33  34  35  36  37  38  39


             THE SUBMILLIMETER TRANSITIONS OF O16=O18 ARE AS
        FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  0  11.5085583  16.9782804  22.4332147  27.8439008  33.3240663  38.7638636  44.2008027  49.635091  55.0667776  60.4958227
      65.922133  71.3455817  76.7660197  82.1832836  87.5971991  93.0075849  98.4142539  103.817015  109.215676  114.610038
      119.999904  125.385076  130.765351  136.140529  141.510407  146.874783  152.233453  157.586213  162.93286  168.273188
      173.606994  178.934071  184.254216  189.567223  194.872886  200.171001  205.461361  210.743761  216.017996

NUG:  7.80360459  13.4006023  18.9096143  24.3897805  29.8563868  35.3150944  40.7684152  46.2175756  51.6631968  57.1055838
      62.5448633  67.9810553  73.4141126  78.843944  84.2704288  89.6934251  95.1127768  100.528316  105.939869  111.347253
      116.750283  122.148768  127.542517  132.931335  138.315026  143.693391  149.066231  154.433346  159.794535  165.149596
      170.498328  175.840526  181.175989  186.504512  191.825892  197.139924  202.446404  207.745127  213.03589  218.318486

NUM:  9.95599302  15.4699833  20.9397261  26.3946879  31.8424085  37.2856152  42.7254607  48.1624549  53.5968051  59.0285605
      64.4576813  69.8840742  75.3076123  80.7281467  86.1455138  91.5595394  96.9700421  102.376835  107.779727  113.178525
      118.573032  123.96305  129.348379  134.72882  140.10417  145.474227  150.838789  156.197651  161.550611  166.897464
      172.238006  177.572031  182.899336  188.219715  193.532962  198.838873  204.137243  209.427864  214.710533  219.985043

         THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
      CM) ARE AS FOLLOWS:

ELF:  0  4.52471402  9.95599302  18.1026533  28.9643852  42.5407754  58.8313077  77.8353625  99.5522168  123.981044  151.120916
      180.970799  213.529557  248.795951  286.768638  327.446173  370.827007  416.909486  465.691857  517.172259  571.348731
      628.219207  687.781518  750.033392  814.972455  882.596228  952.902129  1025.88747  1101.54947  1179.88523  1260.89176
      1344.56596  1430.90463  1519.90446  1611.56204  1705.57358  1802.83634  1902.44571  2004.69818  2109.58981

ELG:  0  2.63267001  8.0246591  16.1460875  26.9888992  40.5497473  56.8267561  75.8185895  97.5241109  121.942238  149.071875
      176.911876  211.461026  246.718026  284.681493  325.349947  368.721815  414.795424  463.569003  515.040682  569.208486
      626.070343  685.624076  747.867408  812.797959  880.413245  950.710681  1023.68758  1099.34115  1177.66849  1258.66662
      1342.33243  1428.66271  1517.65416  1609.30338  1703.60684  1800.56093  1900.16195  2002.40605  2107.28932

ELM:  0  2.63267001  8.0246591  16.1460875  26.9888992  40.5497473  56.8267561  75.8185895  97.5241109  121.942238  149.071875
      176.911876  211.461026  246.718026  284.681493  325.349947  368.721815  414.795424  463.569003  515.040682  569.208486
      626.070343  685.624076  747.867408  812.797959  880.413245  950.710681  1023.68758  1099.34115  1177.66849  1258.66662
      1342.33243  1428.66271  1517.65416  1609.30338  1703.60684  1800.56093  1900.16195  2002.40605  2107.28932

           THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF        (GHZ)
      0  345.017897  508.99604  672.530856  835.848379  999.030374  1162.11139  1325.10673  1488.02259  1650.86046  1813.61914
      1976.29583  2138.88673  2301.38738  2463.79286  2626.09796  2788.29725  2950.38511  3112.35562  3274.20358  3435.92249
      3597.50663  3758.95  3920.2466  4081.39038  4242.37829  4403.19523  4563.84411  4724.31583  4884.60426  5044.70327
      5204.60673  5364.3085  5523.80243  5683.08236  5842.14215  6000.97563  6159.57664  6317.93902  6476.05659
 NUG        (GHZ)
      233.94618  401.739949  566.895974  731.187224  895.071957  1058.7199  1222.20634  1385.56806  1548.82368  1711.98233
      1875.04783  2038.02077  2200.89973  2363.68198  2526.3639  2688.94124  2851.40931  3013.76311  3175.99737  3338.10667
      3500.08542  3661.92794  3823.62847  3985.18118  4146.58015  4307.81948  4468.89317  4629.79523  4790.51964  4951.06034
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        5111.41127  5271.56636  5431.5195  5591.2646  5750.79555  5910.10623  6069.1905  6228.04224  6386.65531  6545.02356
   NUM        (GHZ)
        298.473162  463.778433  627.757195  791.292836  954.611391  1117.79462  1280.87709  1443.87407  1606.79179  1769.63173
        1932.39267  2095.07184  2257.66542  2420.16895  2582.57753  2744.88594  2907.08873  3069.1803  3231.15494  3393.00682
        3554.73007  3716.31874  3877.76686  4039.06841  4200.21735  4361.20761  4522.03312  4682.66778  4843.16548  5003.4601
        5163.56551  5323.47557  5483.18415  5642.68509  5801.97224  5961.03946  6119.88057  6278.48942  6436.85984  6594.98567


REFNO = 7
NINPUT:  0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30  31  32
        33  34  35  36  37  38  39

             THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
        O16-O18 ARE AS FOLLOWS:

FP:     0  56.7220524  57.8989344  58.6563677  59.223578  59.6895224  60.0949461  60.4613313  60.8010839  61.1218718  61.4286909
        61.7249364  62.012997  62.2946028  62.5710377  62.8432748  63.1120656  63.3779997  63.6415466  63.9030845  64.1629223
        64.4213144  64.6784724  64.9345742  65.1897702  65.4441888  65.69794  65.9511191  66.203809  66.456082  66.7080019  66.959625
         67.2110014  67.4621756  67.7131878  67.9640741  68.214867  68.4655961  68.7162886  68.966969

FM:     0  118.759917  64.5269817  62.0384837  60.8612206  60.1056124  59.5394336  59.0747269  58.6707473  58.3060124  57.9681164
        57.6493914  57.3448415  57.0510715  56.7656926  56.4869749  56.2136344  55.9446979  55.679414  55.4171931  55.1575658
        54.9001536  54.6446479  54.3907943  54.1383809  53.88723  53.6371913  53.3881363  53.1399549  52.8925518  52.6458444
        52.3997601  52.1542351  51.9092133  51.6646446  51.4204842  51.1766921  50.9332323  50.6900721  50.447182

             THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
        RELATIVE TO THE GROUND STATE) ARE:

ELP:    -54.2331418  24.6923196  186.340086  429.814385  754.873703  1161.4177  1649.39015  2218.75099  2869.46615  3601.50319
        4414.82925  5309.40998  6285.20893  7342.18722  8480.30331  9699.51289  10999.7688  12381.0208  13843.216  15386.298
        17010.208  18714.8836  20500.2596  22366.2677  24312.8366  26339.8919  28447.3561  30635.1484  32903.1854  35251.3801
        37679.6428  40187.8806  42775.9974  45443.894  48191.4683  51018.615  53925.2257  56911.1885  59976.39  63120.7113

ELM:    -54.2331418  -37.3455452  179.713038  426.432269  753.23606  1161.00161  1649.94566  2220.13759  2871.59649  3604.31905
        4418.28983  5313.48552  6289.87708  7347.43075  8486.10865  9705.86919  11006.6672  12388.4541  13851.1781  15394.7839
        17019.2133  18724.4047  20510.2934  22376.8115  24323.888  26351.4489  28459.4168  30647.7114  32916.2492  35264.9437
        37693.705  40202.4405  42791.0541  45459.447  48207.5169  51035.1586  53942.2639  56928.7212  59994.4162  63139.2311

             THE PREDICTED LMR AND RAMAN LINES CONNECTING
        STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL:    244.24002  407.05638  569.85726  732.636469  895.387813  1058.1051  1220.78214  1383.41274  1545.99071  17[illegible]
        1870.96398  2033.3469  2195.65242  2357.87435  2520.00649  2682.04266  2843.97666  3005.8023  3167.51339  3329.[illegible]
        3490.56714  3651.89742  3813.08838  3974.13383  4135.02758  4295.76342  4456.33518  4616.73666  4776.96167  4937.[illegible]
        5096.8575  5256.51594  5415.97314  5573.22291  5734.25906  5893.07538  6051.6657  6210.02382  6368.14355  [illegible]
```

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THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR O18-O18:

B0 = 38.31373 GHZ = 1.278008468 INVERSE CM;
B1 = -0.000115 GHZ = -3.835987095E-6 INVERSE CM;
B2 = 0 GHZ = 0 INVERSE CM;

LAM0 = 59.496698 GHZ = 1.984596224 INVERSE CM;
LAM1 = 5.211E-5 GHZ = 1.7382025E-6 INVERSE CM;

MU0 = -0.224439 GHZ = -0.007486479196 INVERSE CM;
MU1 = -3.51E-7 GHZ = -1.170809974E-8 INVERSE CM.

TEMP = 296   REFNO = 7   ISOTOPE = 88
K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.439329238  6.699834898  10.79482301  14.84408852  18.87425722  22.89463278  26.90931812  30.92040457  34.92907031
     38.93602977  42.94174138  46.94651283  50.95055832  54.95403157  58.95704575  62.95968604  66.96201776  70.96409186
     74.96594865  78.96762044  82.96913344  86.97050914  90.9717653  94.97291675  98.97397597  102.9749535  106.9758584
I(K,K-1;K,K)
      2  6.504877968  10.71976784  14.80432871  18.84963621  22.87788755  26.89719096  30.91121671  34.92186869  38.93023317
     42.93697519  46.94292474  50.94717218  54.95112068  58.95451663  62.95746821  66.9600571  70.9623461  74.9643843  78.96621064
      82.96785637  86.96934691  90.9707031  94.97194221  98.97307868  102.9741247  106.9750905


I(K,K;K+2,K+1)
     0.06067076183  0.05014510241  0.03851031879  0.03091148398  0.02574277528  0.02203388254  0.01925331333  0.01709543128
     0.01537413188  0.0139702289  0.01280400739  0.01182050365  0.01098014123  0.01025414458  0.009620913863  0.009063957777
     0.008570470644  0.008130359069  0.007735561107  0.007379560416  0.007057033318  0.006763588234  0.006495570518
     0.006249914307  0.006024028705  0.005815709375  0.005623069151
I(K,K+1;K+2,K+1)
     0.4933198775  0.268771928  0.1862888108  0.1415056267  0.1145161729  0.09620934192  0.08297671577  0.07296720524
     0.06513289983  0.05883591923  0.05366567463  0.04934588714  0.04568380927  0.04254086893  0.03981488265  0.0374284845b
     0.03532362675  0.03345306572  0.03178060269  0.03027690538  0.02891816751  0.02768486631  0.02656084081  0.0255325984l
     0.02458878625  0.02371978353  0.02291738357
I(K,K+1;K+2,K+2)
     0.1617886982  0.08023216386  0.05281415149  0.03925267807  0.03120336398  0.0258859599  0.0221166266  0.0193077812?
     0.01713525535  0.01540576621  0.01399700004  0.01282781614  0.01184228565  0.01100061488  0.01027372337  0.009633569073
     0.009082472786  0.008588672746  0.008148338796  0.007753384302  0.00739727599  0.007074678339  0.006781191349  0.006513154293
      0.006267496852  0.006041624834  0.005833331428
```

```
REFNO = 7
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

        THE SUBMILLIMETER TRANSITIONS OF O18-O18 ARE AS
  FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  10.7271442  21.0041762  31.2529109  41.4895838  51.7168826  61.9348264  72.1426101  82.3391046  92.5230323  102.693039
      112.84773  122.985683  133.105462  143.20562  153.284705  163.341257  173.373816  183.380917  193.361096  203.312884
      213.234815  223.125419  232.983226  242.806768  252.594673  262.345171  272.057091

NUG:  12.6364625  22.9688603  33.248005  43.5078406  53.7552159  63.9916419  74.2169814  84.4304492  94.6309632  104.817289
      114.988107  125.142049  135.277715  145.393684  155.488523  165.560789  175.609032  185.631797  195.627626  205.595058
      215.532631  225.438878  235.312336  245.151536  254.955011  264.721294  274.448914

NUM:  14.6888776  24.9659575  35.2147674  45.4515427  55.6789714  65.8970725  76.1050407  86.3017472  96.4859141  106.656188
      116.811172  126.949447  137.069574  147.170109  157.249596  167.306579  177.339596  187.347182  197.327874  207.280203
      217.202701  227.093899  236.952329  246.77652  256.565002  266.316304  276.028955

      THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
  CM) ARE AS FOLLOWS:

ELF:  3.9617129  16.7412722  39.7425457  72.9622191  116.395505  170.036143  233.8764  307.907069  392.117472  486.495455
      591.027394  705.698189  830.49127  965.388591  1110.37064  1265.41641  1430.50346  1605.60784  1790.70414  1985.76549
      2190.76352  2405.6684  2630.44884  2865.07206  3109.50381  3363.70837  3627.64856

ELG:  2.05239461  14.7765882  37.7474517  70.9439622  114.357172  167.979327  231.802029  305.815725  390.009541  484.371206
      588.887017  703.541823  828.319017  963.200527  1108.16682  1263.19688  1428.26824  1603.35696  1788.43761  1983.48331
      2188.4657  2403.35494  2628.11973  2862.72729  3107.14337  3361.33225  3625.25673

ELM:  2.05239461  14.7765882  37.7474517  70.9439622  114.357172  167.979327  231.802029  305.815725  390.009541  484.371206
      588.887017  703.541823  828.319017  963.200527  1108.16682  1263.19688  1428.26824  1603.35696  1788.43761  1983.48331
      2188.4657  2403.35494  2628.11973  2862.72729  3107.14337  3361.33225  3625.25673

        THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF        (GHZ)
      321.591694  629.689362  936.938699  1243.82643  1550.43313  1856.75938  2162.78104  2468.46426  2773.77073  3078.65987
      3383.08983  3687.01802  3990.40136  4293.19649  4595.35984  4896.84769  5197.61624  5497.6216  5796.81982  6095.16693
      6392.61893  6689.13178  6984.66141  7279.16378  7572.5948  7864.91037  8156.0664
 NUG        (GHZ)
      378.831616  688.589107  996.750114  1304.33225  1611.54083  1918.42116  2224.96913  2531.16119  2836.96491  3142.34326
      3447.25672  3751.66424  4055.52386  4358.79299  4661.42866  4963.3876  5264.62634  5565.10128  5864.76869  6163.58479
      6461.50571  6758.48755  7054.48676  7349.45816  7643.35895  7936.14473  8227.77145
 NUM        (GHZ)
      440.361473  748.460577  1055.71217  1362.60297  1669.21357  1975.54453  2281.57172  2587.26129  2892.57493  3197.47207
      3501.91085  3805.84866  4109.24246  4412.04886  4714.2243  5015.72506  5316.50734  5616.52724  5915.74084  6214.10414
      6511.57315  6808.10382  7103.65211  7398.17394  7691.62525  7983.96193  8275.13989
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REFNO = 7
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

        THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
      O18=O18 ARE AS FOLLOWS:

FP:   57.2399223  58.8997449  59.6114151  60.5058186  61.1076961  61.6617782  62.1880871  62.696935  63.1941781  63.6833923
      64.1668875  64.6462245  65.1224977  65.5964993  66.0688177  66.5399008  67.0100965  67.4796801  67.9488733  68.4178573
      68.8867822  69.3557745  69.8249414  70.2943757  70.76415[illegible]  71.2343584  71.7050407

FM:   118.769165  61.5298572  59.8714692  58.9620532  58.2707236  57.6727397  57.1233711  56.6025952  56.1001002  55.6100297
      55.1288077  54.6541245  54.1844193  53.7185974  53.255867  52.7956395  52.337467  51.8810016  51.425968  50.9721445
      50.5193501  50.0674343  49.616271  49.1657526  48.7157867  48.2662928  47.8171998

        THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
      RELATIVE TO THE GROUND STATE) ARE:

ELP:  61.5292425  442.990971  1131.64013  2126.84648  3428.34176  5035.89355  6949.24999  9168.12478  11692.1919  14521.0834
      17654.3886  21091.6532  24832.3794  28876.0254  33222.0054  37869.6898  42818.4048  48067.4324  53616.0108  59463.3338
      65608.5511  72050.7685  78789.0474  85822.4051  93149.8149  100770.206  108682.463

ELM:  0  440.360858  1131.58008  2128.39025  3431.17873  5039.88259  6954.31471  9174.21912  11699.286  14529.1568  17663.4267
      21101.6453  24843.3175  28887.9033  33234.8184  37883.4341  42833.0774  48083.0311  53632.5337  59480.7795  65626.9186
      72070.0569  78809.2561  85843.5337  93171.8633  100793.174  108706.351

        THE PREDICTED LMR AND RAMAN LINES CONNECTING
      STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL:  383.121551  689.560832  995.900752  1302.09715  1608.10587  1913.88275  2219.38364  2524.56436  2829.38076  3133.78868
      3437.74396  3741.20244  4044.11996  4346.45236  4648.15548  4949.18516  5249.49724  5549.0[illegible]756  5847.79196  6145.68628
      6442.68637  6738.74805  7033.82717  7327.87957  7620.86109  7912.72757  8203.43485
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THE PARAMETERS ARE AS FOLLOWS ACCORDING TO
ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE (REF. 5),
FOR V' = V'' = 1:

B0 = 42.62790931 GHZ;
B1 = -0.0001451055455 GHZ;
B2 = 0 GHZ;

LAM0 = 59.75013584 GHZ;
LAM1 = 0 GHZ;

MU0 = -0.2689138348 GHZ;
MU1 = 0 GHZ.

IN UNITS OF INVERSE CM, THE ABOVE PARAMETERS ARE:
1.421914  -4.8402E-6  0  1.99305  0  -0.00897  0


K = 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

I(K,K+1;K,K)
      2.45052694  6.709147694  10.80196626  14.84982434  18.87903487  22.89872258  26.91289212  30.92357824  34.93192463
      38.93862361  42.94411885  46.94870781  50.95259738  54.95593594  58.95883264  62.9613696  66.96360978  70.96560223
      74.96738578  78.96899154  82.97044472  86.97176598  90.97297243  94.97407832  98.97509564  102.9760346  106.9769037
I(K,K-1;K,K)
      2  6.534738507  10.73463631  14.81412516  18.8569198  22.88367863  26.90199576  30.91532223  34.92645307  38.93341444
      42.93983556  46.94512371  50.94955421  54.95331984  58.95655962  62.95937634  66.96184763  70.96403322  74.96597981
      78.96772446  82.96929693  86.9707214  90.97201775  94.97320242  98.97428917  102.9752896  106.9762135


I(K,K;K+2,K+1)
      0.04947306999  0.04085230595  0.03136/0688  0.02517565708  0.02096513066  0.01794408389  0.01567930775  0.013921758
      0.01251981759  0.01137639303  0.01042660661  0.009625526731  0.008941081205  0.008349779073  0.007834028313  0.007380397827
      0.006978458373  0.006619989776  0.006298426385  0.006008461358  0.005745759202  0.005506743555  0.005288438234
      0.005088346572  0.004904358873  0.004734679685  0.004577772729
I(K,K+1;K+2,K+1)
      0.4041168877  0.2192673234  0.151019597  0.1152928698  0.09328653298  0.07836553065  0.06758266681  0.05942734524
      0.05304488924  0.04791511549  0.043/0342297  0.04018461288  0.03720161578  0.03464152114  0.03242107516  0.03047754256
      0.02876275174  0.02723910034  0.02587680726  0.02465197984  0.02354522724  0.02254064 81  0.02162507967  0.02078753279
      0.0200187613  0.01931092992  0.01865735523
I(K,K+1;K+2,K+2)
      0.13192816  0.06536368952  0.04301769435  0.03196908835  0.02541227959  0.02108116149  0.01801110224  0.0157233981A
      0.01395397626  0.01254539582  0.01139802959  0.01044578901  0.009643121656  0.008957617396  0.008365591969  0.00784933F06
      0.007395353288  0.006993162945  0.006634517052  0.006312829945  0.006022781058  0.0057600253  0.005520979 49  0.0053[illegible]
      0.005102574108  0.004918601759  0.004748948 45
```

```
REFNO = 5
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE SUBMILLIMETER TRANSITIONS OF O16-O16 ARE AS
     FOLLOWS (IN UNITS OF INVERSE CM):

NUF:  12.1311775  23.5757022  34.9824514  46.373412  57.7523122  69.1192944  80.473395  91.813216  103.13716  114.443527
      125.730561  136.996473  148.239452  159.457674  170.649307  181.81251  192.94544  204.04625  215.11309  226.144109
      237.137455  248.091273  259.003709  269.872908  280.697014  291.474171  302.202522

NUG:  14.0210227  25.5377415  36.9830915  48.4029048  59.8064963  71.1960099  82.5713768  93.9316594  105.275521  116.601422
      127.907709  139.19266  150.454514  161.691482  172.901755  184.083513  195.234929  206.354165  217.439383  228.488737
      239.500381  250.472467  261.403144  272.290559  283.13286  293.928193  304.674704

NUM:  16.1083075  27.5528322  38.9595814  50.350542  61.7294422  73.0964244  84.450525  95.790346  107.11429  118.420657
      129.707691  140.973603  152.216582  163.434804  174.626437  185.78964  196.92257  208.02338  219.09022  230.121239
      241.114585  252.068403  262.980839  273.850038  284.674144  295.451301  306.179652

          THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
     CM) ARE AS FOLLOWS:

ELF:  3.97713  18.1955924  43.7863852  80.7453265  129.066376  188.741634  259.761343  342.113886  435.785788  540.761716
      657.024478  784.555021  923.332437  1073.33396  1234.53495  1406.90894  1590.42758  1785.06066  1990.77612  2207.54005
      2435.31666  2674.06832  2923.75553  3184.33693  3455.76932  3738.00762  4031.0049

ELG:  2.08728484  16.233553  41.7857451  78.7158337  127.012192  186.664918  257.663361  339.995442  433.647427  538.603821
      654.84733  782.358834  921.117375  1071.10015  1232.28251  1404.63794  1588.13809  1782.75274  1988.44983  2205.19542
      2432.95373  2671.68713  2921.35609  3181.91928  3453.33348  3735.5536  4028.53272

ELM:  2.08728484  16.233553  41.7857451  78.7158337  127.012192  186.664918  257.663361  339.995442  433.647427  538.603821
      654.84733  782.358834  921.117375  1071.10015  1232.28251  1404.63794  1588.13809  1782.75274  1988.44983  2205.19542
      2432.95373  2671.68713  2921.35609  3181.91928  3453.33348  3735.5536  4028.53272

          THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

 NUF        (GHZ)
     363.683553  706.78177  1048.74751  1390.23992  1731.37076  2072.14432  2412.53169  2752.49097  3091.97426  3430.93062
     3769.3074  4107.05094  4444.10697  4780.42092  5115.93751  5450.60192  5784.35877  6117.15267  6448.9282  6779.62983
     7109.20204  7437.58925  7764.73586  8090.58625  8415.08479  8738.17582  9059.80369
 NUG        (GHZ)
     420.339686  765.60223  1108.72519  1451.08258  1792.95365  2134.40268  2475.4276  2816.00031  3156.08073  3495.6227
     3834.57665  4172.89098  4510.51287  4847.38867  5183.4642  5518.6849  5852.99592  6186.34225  6518.66871  6849.92001
     7180.0408  7508.97566  7836.66909  8163.06559  8488.10961  8811.74556  9133.91785
 NUM        (GHZ)
     482.914911  826.013128  1167.97887  1509.47128  1850.60212  2191.37567  2531.76305  2871.72233  3211.20562  3550.16195
     3888.53875  4226.2823  4563.33833  4899.65217  5235.16887  5569.83328  5903.59013  6236.38403  6568.15955  68[illegible]6119
     7228.4334  7556.82061  7883.96722  8209.81761  8534.31614  8857.40718  9179.03505
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REFNO = 5
NINPUT:  1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37  39  41  43  45  47  49  51  53

          THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
     O16=O16 ARE AS FOLLOWS:

FP:  56.6561325  58.82046  59.9776816  60.5426626  61.5828925  62.2583648  62.8959113  63.5093366  64.1064699  64.6920826
     65.2692485  65.8400372  66.4058933  66.9678557  67.5266906  68.0829759  68.6371552  69.1895748  69.7405093  70.2901789
     70.8387624  71.3864063  71.9332322  72.4793414  73.0248193  73.5697382  74.1141599

FM:  119.231358  62.5752253  60.4108978  59.2536763  58.3886953  57.6484454  56.972993  56.3354466  55.7220213  55.124888
     54.5392753  53.9621093  53.3913206  52.8254646  52.2635022  51.7046672  51.1483819  50.5942027  50.041783  49.4908485
     48.9411789  48.3925955  47.8449515  47.2981256  46.7520164  46.2065385  45.6616196

          THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
     RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.5752253  486.669676  1252.70512  2359.84133  3807.72971  5596.07347  7724.55323  10192.8069  13000.4228  16146.9363
     19631.8291  23454.5278  27614.4042  32110.7747  36942.9001  42109.986  47611.1822  53445.5827  59612.2262  66110.0956
     72938.118  80095.165  87580.0524  95391.5403  103528.333  111989.079  120772.373

ELM: 0  482.914911  1252.27191  2361.43031  3810.92391  5600.68336  7730.47615  10199.9808  13008.8072  16156.5035  19642.559
     23466.4057  27627.4188  32124.9171  36958.1633  42126.3643  47628.6709  53464.1781  59631.925  66130.8949  72960.0156
     80118.1588  87604.1407  95416.7215  103554.606  112016.443  120800.825

          THE PREDICTED LMR AND RAMAN LINES CONNECTING
     STATES N=J WITH STATES N'=J'=N+2 (IN GHZ) ARE:

ERL: 426.258778  767.192668  1108.00119  1448.62861  1789.01923  2129.11731  2468.84714  2808.21299  3147.09915  3485.4699
     3823.26951  4160.44226  4496.93[illegible]44  4832.68432  5167.64218  5501.7503  5834.95297  6167.19446  6498.41904  6828.57101
     7157.59464  7485.4342  7812.03399  8137.33827  8461.29133  8783.83744  9104.92089
```

APPENDIX C

ADDITIONAL APL PARAMETER-SETTING PROGRAMS

The parameter-setting program PARAMSTEIN (Fig. 1, p. 8) gave B_0, B_1, B_2, λ_0, λ_1, μ_0, and μ_1 for $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$, according to Steinbach and Gordy,[7] for the vibrational ground state, v = 0. These seven parameters (for $^{16}O^{16}O$ only) according to Refs. 1 through 6 (for v = 0) are contained in the APL program PARAMETERS (Fig. C-1). The APL program containing the parameters for the upper vibrational state, v = 1, in $^{16}O_2$, according to Ref. 5, is PARAMSTEINUPPER (Fig. C-2). In this program, $\Delta G_{1/2}$ is represented as GV.

```
     ∇ PARAMETERS;X;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1;REFTEXT1;REFTEXT2;REFTEXT3;REFTEXT4;REFTEXT5;
       REFTEXT6;REFTEXTX
[1]    ⍝ 'REFNO' IS AN INTEGER FROM 1 TO 6, CORRESPONDING TO ONE
[2]    ⍝ OF THE SIX REFERENCES LISTED IN 'REFTEXT'.
[3]    VECB0←43.1029 43.100589 43.100518 43.100518,(1.437708×SPEEDOFLIGHT),43.1004608
[4]    VECB1←¯0.0001471499 ¯0.00014 ¯0.0001449629 ¯0.00014496,(¯4.84E¯6×SPEEDOFLIGHT),¯0.0001452
[5]    VECB2←0 0 ¯1.57E¯10 ¯1.7E¯10 0 0
[6]    VECLAM0←59.50157 59.501346 59.501342 59.501342,(1.5×1.3239×SPEEDOFLIGHT),59.501342
[7]    VECLAM1←5.678E¯5 5.845E¯5 5.847E¯5 5.847E¯5 0 5.847E¯5
[8]    VECMU0←¯0.25267 ¯0.2525917 ¯0.2525865 ¯0.2525865,(¯0.008436×SPEEDOFLIGHT),¯0.2525865
[9]    VECMU1←0 ¯2.455E¯7 ¯2.464E¯7 ¯2.464E¯7 0 ¯2.464E¯7
[10]   REFTEXT1←'TINKHAM AND STRANDBERG'
[11]   REFTEXT2←'WILHEIT AND BARRETT'
[12]   REFTEXT3←'WELCH AND MIZUSHIMA'
[13]   REFTEXT4←'EVENSON AND MIZUSHIMA'
[14]   REFTEXT5←'ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE'
[15]   ⍝    BASED ON THEIR TABLES II AND X, AND D0 VALUE ON P. 118.
[16]   REFTEXT6←'TOMUTA, MIZUSHIMA, HOWARD, AND EVENSON'
[17]   ⍝    BASED ON PRIVATE COMMUNICATION FROM M. MIZUSHIMA TO M. GREENEBAUM, 7/7/75.
[18]   'PLEASE TYPE REFERENCE NUMBER'
[19]   X←REFNO←⎕
[20]   B0←VECB0[X]
[21]   B1←VECB1[X]
[22]   B2←VECB2[X]
[23]   LAM0←VECLAM0[X]
[24]   LAM1←VECLAM1[X]
[25]   MU0←VECMU0[X]
[26]   MU1←VECMU1[X]
[27]   REFTEXTX←6 42⍴' '
[28]   REFTEXTX[1;⍳⍴REFTEXT1]←REFTEXT1
[29]   REFTEXTX[2;⍳⍴REFTEXT2]←REFTEXT2
[30]   REFTEXTX[3;⍳⍴REFTEXT3]←REFTEXT3
[31]   REFTEXTX[4;⍳⍴REFTEXT4]←REFTEXT4
[32]   REFTEXTX[5;⍳⍴REFTEXT5]←REFTEXT5
[33]   REFTEXTX[6;⍳⍴REFTEXT6]←REFTEXT6
[34]   '       THANK YOU.

       '
[35]   'THE PARAMETERS ACCORDING TO ';REFTEXTX[X;];'
       (REF. ';X;') ARE AS FOLLOWS:

       '
[36]   'B0 = ';B0;' GHZ;  '
[37]   'B1 = ';B1;' GHZ;  '
[38]   'B2 = ';B2;' GHZ;
       '
[39]   'LAM0 = ';LAM0;' GHZ;    '
[40]   'LAM1 = ';LAM1;' GHZ;
       '
[41]   'MU0 = ';MU0;' GHZ;    '
[42]   'MU1 = ';MU1;' GHZ.
       '
[43]   'TEMPERATURE IS ASSUMED TO BE 296K;IF THIS IS INCORRECT, WRITE:'
[44]   '  ''TEMP←(   )'' WHERE DESIRED NUMBER IS INSERTED.'
[45]   TEMP←296
[46]   ⍝    REVISED 10 JULY 1975
     ∇
```

Fig. C-1: Listing of APL function PARAMETERS

```
     ∇ PARAMSTEINUPPER;X;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1;REFTEXT5;VECGV
[1]    ⍝ 'REFNO' IS 5, CORRESPONDING TO 'REFTEXT5'; 'V' IS 0 OR 1,
[2]    ⍝ CORRESPONDING TO V''.  (ONLY V'=V'' TRANSITIONS CONSIDERED.)
[3]    VECB0←(1.437708 1.421914)×SPEEDOFLIGHT
[4]    VECB1←(¯4.84E¯6 ¯4.8402E¯6)×SPEEDOFLIGHT
[5]    VECB2←0 0
[6]    VECLAM0←1.5×(1.3239 1.3287)×SPEEDOFLIGHT
[7]    VECLAM1←0 0
[8]    VECMU0←(¯8.436 ¯8.97)×0.001×SPEEDOFLIGHT
[9]    VECMU1←0 0
[10]   VECGV←0 1556.378⍝ INVERSE CM
[11]   REFTEXT5←'ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE (REF. 5),
FOR V'' = V'''' = '
[12]   VV←1;REFNO←5
[13]   X←VV+1
[14]   B0←VECB0[X]
[15]   B1←VECB1[X]
[16]   B2←VECB2[X]
[17]   LAM0←VECLAM0[X]
[18]   LAM1←VECLAM1[X]
[19]   MU0←VECMU0[X]
[20]   MU1←VECMU1[X]
[21]   GV←VECGV[X]
[22]   'THE PARAMETERS ARE AS FOLLOWS ACCORDING TO
';REFTEXT5;VV;':

'
[23]   'B0 = ';B0;' GHZ;   '
[24]   'B1 = ';B1;' GHZ;   '
[25]   'B2 = ';B2;' GHZ;
       '
[26]   'LAM0 = ';LAM0;' GHZ;    '
[27]   'LAM1 = ';LAM1;' GHZ;
       '
[28]   'MU0 = ';MU0;' GHZ;    '
[29]   'MU1 = ';MU1;' GHZ.
       '
[30]   'IN UNITS OF INVERSE CM, THE ABOVE PARAMETERS ARE:'
[31]   +PARAMVEC←(B0,B1,B2,LAM0,LAM1,MU0,MU1)÷SPEEDOFLIGHT
[32]   'TEMPERATURE IS ASSUMED TO BE 296K;IF THIS IS INCORRECT, WRITE:'
[33]   '   ''TEMP←(   )'' WHERE DESIRED NUMBER IS INSERTED.'
[34]   TEMP←296
[35]   X←1⍝  CALCULATION FOR O16=O16 ONLY, FOR V'=V''=1 ONLY.
[36]   ⍝     THIS IS A MODIFIED FORM OF 'PARAMUPPER' FOR USE WITH 'ABCD' OR
[37]   ⍝ 'ABCDLP' (THEORY OF W. R. STEINBACH INSTEAD OF TINKHAM AND STRANDBERG)
[38]   ⍝ VERSION OF 28 JULY 1975.
     ∇
```

Fig. C-2: Listing of APL function PARAMSTEINUPPER

APPENDIX D

Temperature Dependence of Rotational State Sum for Molecular Oxygen

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16

EMPLOYING THE PARAMETERS OF REF. 1 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64467	55.83416	1.01452
100K	73.32311	72.51190	1.01119
125K	91.45851	90.63987	1.00903
150K	109.59893	108.76785	1.00764
175K	127.74352	126.89582	1.00668
200K	145.89184	145.02380	1.00599
225K	164.04365	163.15177	1.00547
250K	182.19881	181.27975	1.00507
273K	198.90444	197.95748	1.00478
275K	200.35724	199.40772	1.00476
296K	215.61279	214.63522	1.00455
300K	218.51886	217.53570	1.00452
325K	236.68364	235.66367	1.00433

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16

EMPLOYING THE PARAMETERS OF REF. 2 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64683	55.83716	1.01450
100K	73.32569	72.51579	1.01117
125K	91.46140	90.64473	1.00901
150K	109.60200	108.77368	1.00762
175K	127.74661	126.90263	1.00665
200K	145.89481	145.03157	1.00595
225K	164.04635	163.16052	1.00543
250K	182.20110	181.28947	1.00503
273K	198.90622	197.96810	1.00474
275K	200.35896	199.41841	1.00472
296K	215.61392	214.64673	1.00451
300K	218.51987	217.54736	1.00447
325K	236.68380	235.67631	1.00427

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 3 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64740	55.83725	1.01451
100K	73.32662	72.51591	1.01118
125K	91.46282	90.64488	1.00902
150K	109.60401	108.77386	1.00763
175K	127.74932	126.90284	1.00667
200K	145.89832	145.03181	1.00597
225K	164.05077	163.16079	1.00545
250K	182.20653	181.28976	1.00506
273K	198.91267	197.96842	1.00477
275K	200.36551	199.41874	1.00475
296K	215.62149	214.64708	1.00454
300K	218.52765	217.54772	1.00450
325K	236.69291	235.67669	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 4 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64740	55.83725	1.01451
100K	73.32662	72.51591	1.01118
125K	91.46282	90.64488	1.00902
150K	109.60401	108.77386	1.00763
175K	127.74932	126.90284	1.00667
200K	145.89832	145.03181	1.00597
225K	164.05077	163.16079	1.00545
250K	182.20653	181.28976	1.00506
273K	198.91268	197.96842	1.00477
275K	200.36551	199.41874	1.00475
296K	215.62150	214.64708	1.00454
300K	218.52765	217.54772	1.00450
325K	236.69291	235.67669	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 5 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64484	55.83610	1.01448
100K	73.32372	72.51442	1.01116
125K	91.45955	90.64302	1.00901
150K	109.60038	108.77163	1.00762
175K	127.74532	126.90023	1.00666
200K	145.89396	145.02884	1.00597
225K	164.04605	163.15744	1.00545
250K	182.20144	181.28605	1.00505
273K	198.90725	197.96436	1.00476
275K	200.36006	199.41465	1.00474
296K	215.61574	214.64268	1.00453
300K	218.52183	217.54326	1.00450
325K	236.68672	235.67186	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 6 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64749	55.83732	1.01451
100K	73.32675	72.51600	1.01118
125K	91.46299	90.64500	1.00902
150K	109.60423	108.77400	1.00763
175K	127.74958	126.90300	1.00667
200K	145.89863	145.03200	1.00598
225K	164.05114	163.16100	1.00546
250K	182.20695	181.29001	1.00506
273K	198.91315	197.96869	1.00477
275K	200.36599	199.41901	1.00475
296K	215.62202	214.64737	1.00454
300K	218.52818	217.54801	1.00451
325K	236.69350	235.67701	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 7 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64748	55.83732	1.01451
100K	73.32672	72. 1600	1.01118
125K	91.46295	90.64500	1.00902
150K	109.60416	108.77401	1.00763
175K	127.74949	126.90301	1.00667
200K	145.89851	145.03201	1.00597
225K	164.05098	163.16101	1.00545
250K	182.20676	181.29001	1.00506
273K	198.91292	197.96869	1.00477
275K	200.36575	199.41901	1.00475
296K	215.62175	214.64737	1.00454
300K	218.52791	217.54801	1.00450
325K	236.69317	235.67701	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O18
EMPLOYING THE PARAMETERS OF REF. 7 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	116.28488	118.23962	0.98347
100K	151.60712	153.55795	0.98730
125K	190.01360	191.94744	0.98993
150K	228.42996	230.33693	0.99172
175K	266.85466	268.72642	0.99303
200K	305.28693	307.11590	0.99404
225K	343.72634	345.50539	0.99485
250K	382.17263	383.89488	0.99551
273K	417.54915	419.21321	0.99603
275K	420.62564	422.28437	0.99607
296K	452.93128	454.53154	0.99648
300K	459.08526	460.67386	0.99655
325K	497.55143	499.06334	0.99697

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O18=O18
EMPLOYING THE PARAMETERS OF REF. 7 (V = 0)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	63.28076	62.81336	1.00744
100K	82.04495	81.57580	1.00575
125K	102.44779	101.96975	1.00469
150K	122.85599	122.36370	1.00402
175K	143.26871	142.75765	1.00358
200K	163.68549	163.15160	1.00327
225K	184.10612	183.54555	1.00305
250K	204.53043	203.93950	1.00290
273K	223.32398	222.70193	1.00279
275K	224.95834	224.33344	1.00279
296K	242.12053	241.46436	1.00272
300K	245.38980	244.72739	1.00271
325K	265.82476	265.12134	1.00265

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, O16=O16
EMPLOYING THE PARAMETERS OF REF. 5 (V = 1,

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	57.22604	56.45631	1.01363
100K	74.09050	73.31988	1.01051
125K	92.42815	91.64985	1.00849
150K	110.77088	109.97982	1.00719
175K	129.11783	128.30979	1.00630
200K	147.46858	146.63976	1.00565
225K	165.82288	164.96973	1.00517
250K	184.18059	183.29969	1.00481
273K	201.07261	200.16327	1.00454
275K	202.54161	201.62966	1.00452
296K	217.96740	217.02684	1.00433
300K	220.90590	219.95963	1.00430
325K	239.27341	238.28960	1.00413

APPENDIX E

Comparison of $^{16}O^{16}O$ (v = 0) Line Strengths Computed by Us at 273 and 296K with Theoretical Results Given in Ref. 8

See text, pp. 27 and 34 for discussion of this Appendix, which was computed using the APL program GBBSTRENGTH. It is assumed that the cm-atm quoted in Ref. 8 refers to 273K and 1 atm, so that 1 $(\text{cm-atm})_{STP}$ = 2.686754(84) E19 molecule cm^{-2} (Loschmidt's constant, L_o).[13,23]

NOTE ADDED IN PROOF: The factor L_o used in the APL program GBBSTRENGTH should have been replaced by $L_o/0.99519$ in computing the integrated line strength in units of cm^{-1} per $(\text{cm-atm})_{STP}$ (see p. 17 of text). The 0.5% change in our computed line strengths does not affect the conclusions to be drawn from the comparison, i. e., that the results of Ref. 8 may be in error by as much as a factor of 2. Note also that the APL program GBBSTRENGTH was used only in generating this Appendix; the line strengths elsewhere in this report, given in units of cm^{-1} per molecule cm^{-2}, have been calculated correctly.

```
TEMP = 273K,    KT = 189.7 INVERSE CM,    X = 1
REFNO = 7
NINPUT: 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37
        39  41  43  45  47  49  51  53

THE LINESTRENGTHS OF THE SUBMILLIMETER TRANSITIONS OF O16=O16, IN
UNITS OF 1.0E=6 INVERSE CM PER CM=ATM (AT STP), ARE AS FOLLOWS:

SF:    0.6996  1.959  2.803  3.152  3.057  2.65  2.09  1.514  1.015  0.6316
       0.3661  0.1981  0.1002  0.04744  0.02105  0.008763  0.003424  0.001257
       0.0004336  0.0001406  4.293E=5  1.233E=5  3.338E=6  8.5E=7  2.041E=7
       4.622E=8  9.868E=9

SG:    7.636  12.37  15.14  15.79  14.68  12.33  9.529  6.801  4.504  2.777
       1.597  0.8586  0.432  0.2036  0.09  0.03733  0.01454  0.005324  0.001832
       0.0005931  0.0001807  5.181E=5  1.399E=5  3.561E=6  8.541E=7  1.931E=7
       4.12E=8

SH:    3.26  4.261  4.754  4.71  4.228  3.479  2.643  1.862  1.221  0.7465
       0.4264  0.2279  0.1141  0.05357  0.02359  0.009757  0.00379  0.001384
       0.0004752  0.0001535  4.668E=5  1.337E=5  3.604E=6  9.159E=7  2.194E=7
       4.956E=8  1.056E=8


GEBBIE, BURROUGHS, AND BIRD, PROC. ROY. SOC. (LONDON) A, VOL. 310, PP.
579 TO 590 (1969) GIVE FOR THE FIRST SEVERAL LINES (IN THE SAME UNITS):

SF:    0.62  1.5  1.8  1.8  1.4

SG:    5.7  8.7  9.5  8.3  6.3

SH:    2.1  2.9  2.9  2.4  1.8


RATIOS OF OUR RESULTS FOR K = 1 THROUGH 9 TO THOSE OF GEBBIE, ET AL:

F:     1.128  1.306  1.557  1.751  2.183

G:     1.34  1.422  1.593  1.902  2.325

H:     1.553  1.469  1.639  1.962  2.349
```

```
TEMP = 296K;    KT = 205.7 INVERSE CM;    X = 1
REFNO = 7
NINPUT: 1  3  5  7  9  11  13  15  17  19  21  23  25  27  29  31  33  35  37
        39  41  43  45  47  49  51  53

THE LINESTRENGTHS OF THE SUBMILLIMETER TRANSITIONS OF O16-O16, IN
UNITS OF 1.0E-6 INVERSE CM PER CM-ATM (AT STP), ARE AS FOLLOWS:

SF:   0.5977  1.687  2.446  2.799  2.775  2.471  2.081  1.511  1.055  0.6868
      0.4185  0.2391  0.1283  0.06477  0.03078  0.01378  0.00582  0.002319
      0.0008725  0.0003101  0.0001041  3.307E-5  9.933E-6  2.823E-6  7.596E-7
      1.935E-7  4.671E-8

SQ:   6.521  10.65  13.2  14.01  13.29  11.5  9.165  6.781  4.678  3.018  1.825
       1.036  0.553  0.2778  0.1315  0.05869  0.02471  0.009818  0.003685
      0.001307  0.000438  0.0001389  4.165E-5  1.182E-5  3.176E-6  8.083E-7
      1.949E-7

SH:   2.786  3.67  4.148  4.182  3.838  3.244  2.543  1.857  1.268  0.8115
      0.4874  0.2751  0.1461  0.07312  0.03449  0.01834  0.00644  0.002553
      0.0009559  0.0003383  0.0001132  3.583E-5  1.073E-5  3.041E-6  8.16E-7
      2.074E-7  4.995E-8


GEBBIE, BURROUGHS, AND BIRD, PROC. ROY. SOC. (LONDON) A, VOL. 310, PP.
579 TO 590 (1969) GIVE FOR THE FIRST SEVERAL LINES (IN THE SAME UNITS):

SF:   0.62  1.5  1.8  1.8  1.4

SQ:   5.7  8.7  9.5  8.3  6.3

SH:   2.1  2.9  2.9  2.4  1.8


RATIOS OF OUR RESULTS FOR K = 1 THROUGH 9 TO THOSE OF GEBBIE, ET AL:

F:    0.964  1.125  1.359  1.555  1.982

G:    1.144  1.224  1.39  1.688  2.11

H:    1.326  1.266  1.43  1.742  2.132
```

APPENDIX F

RRI Absorption Line Parameters for Molecular Oxygen Isotopes $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$ (AFCRL Format)

In the following eight file listings, the contents are labelled at the top of each page with the file names as well as brief descriptions of the contents. The units are as follows:

FREQ: Transition frequency: (cm^{-1})

STRENGTH: Line strength at 296K: $(cm^{-1}/\text{molecule } cm^{-2})$

WIDTH: Line half-width at half-maximum: $(cm^{-1}\ atm^{-1})$

E'': Energy of lower state of the transition, with respect to the ground state, including $\Delta G_{1/2}$: (cm^{-1})

The sequence of the eight file listings is as follows:

AF760K15V0: Microwave fine structure lines of $^{16}O^{16}O$, v = 0.

AF7K15V0: Submillimeter rotational lines of $^{16}O^{16}O$, v = 0.

AF760K25V0: Microwave fine structure lines of $^{16}O^{18}O$, v = 0.

AF7K25V0: Submillimeter rotational lines of $^{16}O^{18}O$, v = 1.

AF760K35V0: Microwave fine structure lines of $^{18}O^{18}O$, v = 0.

AF7K35V0: Submillimeter rotational lines of $^{18}O^{18}O$, v = 0.

AF560K15V1: Microwave fine structure lines of $^{16}O^{16}O$, v = 1.

AF5K15V1: Submillimeter rotational lines of $^{16}O^{16}O$, v = 1.

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF760K15V0 80, 81, ETC.; REF. 7, 016-016 MICROWAVE LINES, KHUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MC
1	1.54817	2.06E-33	.032	4074.552	0	53	53	0	52	53	53-	75	66	7
2	1.56499	8.55E-33	.032	3778.223	0	51	51	0	50	51	51-	75	66	7
3	1.58183	3.36E-32	.032	3492.781	0	49	49	0	48	49	49-	75	66	7
4	1.59871	1.25E-31	.032	3218.270	0	47	47	0	46	47	47-	75	66	7
5	1.61561	4.41E-31	.032	2954.737	0	45	45	0	44	45	45-	75	66	7
6	1.63255	1.47E-30	.032	2702.225	0	43	43	0	42	43	43-	75	66	7
7	1.64953	4.62E-30	.032	2460.774	0	41	41	0	40	41	41-	75	66	7
8	1.66655	1.38E-29	.032	2230.425	0	39	39	0	38	39	39-	75	66	7
9	1.68362	3.87E-29	.032	2011.215	0	37	37	0	36	37	37-	75	66	7
10	1.70076	1.03E-28	.032	1803.180	0	35	35	0	34	35	35-	75	66	7
11	1.71796	2.58E-28	.032	1606.353	0	33	33	0	32	33	33-	75	66	7
12	1.73524	6.09E-28	.032	1420.767	0	31	31	0	30	31	31-	75	66	7
13	1.75262	1.36E-27	.032	1246.452	0	29	29	0	28	29	29-	75	66	7
14	1.77012	2.85E-27	.032	1083.436	0	27	27	0	26	27	27-	75	66	7
15	1.78776	5.63E-27	.032	931.745	0	25	25	0	24	25	25-	75	66	7
16	1.80556	1.05E-26	.038	791.405	0	23	23	0	22	23	23-	75	66	7
17	1.82363	1.83E-26	.035	662.437	0	21	21	0	20	21	21-	75	66	7
18	1.84199	3.00E-26	.037	544.863	0	19	19	0	18	19	19-	75	66	7
19	1.86075	4.60E-26	.038	438.702	0	17	17	0	16	17	17-	75	66	7
20	1.87679	2.74E-26	.045	2.084	0	1	1	0	2	1	1+	75	66	7
21	1.88008	6.58E-26	.038	343.970	0	15	15	0	14	15	15-	75	66	7
22	1.90026	8.77E-26	.039	260.683	0	13	13	0	12	13	13-	75	66	7
23	1.92175	1.08E-25	.041	188.853	0	11	11	0	10	11	11-	75	66	7
24	1.94548	1.22E-25	.043	128.492	0	9	9	0	8	9	9-	75	66	7
25	1.94957	7.55E-26	.044	16.388	0	3	3	0	4	3	3+	75	66	7
26	1.97351	1.26E-25	.044	79.607	0	7	7	0	6	7	7-	75	66	7
27	1.98774	1.11E-25	.042	42.224	0	5	5	0	6	5	5+	75	66	7
28	2.01159	1.13E-25	.044	42.200	0	5	5	0	4	5	5-	75	66	7
29	2.01589	1.31E-25	.041	79.565	0	7	7	0	8	7	7+	75	66	7
30	2.03976	1.35E-25	.040	128.398	0	9	9	0	10	9	9+	75	66	7
31	2.06143	1.25E-25	.039	188.714	0	11	11	0	12	11	11+	75	66	7
32	2.08181	1.05E-25	.038	260.501	0	13	13	0	14	13	13+	75	66	7
33	2.08432	8.41E-26	.047	16.253	0	3	3	0	2	3	3-	75	66	7
34	2.10139	8.23E-26	.034	343.748	0	15	15	0	16	15	15+	75	66	7
35	2.12042	5.97E-26	.036	438.442	0	17	17	0	18	17	17+	75	66	7
36	2.13907	4.04E-26	.035	544.566	0	19	19	0	20	19	19+	75	66	7
37	2.15746	2.56E-26	.035	662.103	0	21	21	0	22	21	21+	75	66	7
38	2.17564	1.52E-26	.032	791.034	0	23	23	0	24	23	23+	75	66	7
39	2.19368	8.49E-27	.032	931.339	0	25	25	0	26	25	25+	75	66	7
40	2.21160	4.45E-27	.032	1082.994	0	27	27	0	28	27	27+	75	66	7
41	2.22943	2.20E-27	.032	1245.975	0	29	29	0	30	29	29+	75	66	7
42	2.24720	1.02E-27	.032	1420.855	0	31	31	0	32	31	31+	75	66	7
43	2.26492	4.48E-28	.032	1605.806	0	33	33	0	34	33	33+	75	66	7
44	2.28260	1.85E-28	.032	1802.598	0	35	35	0	36	35	35+	75	66	7
45	2.30026	7.24E-29	.032	2010.599	0	37	37	0	38	37	37+	75	66	7
46	2.31789	2.67E-29	.032	2229.774	0	39	39	0	40	39	39+	75	66	7
47	2.33551	9.29E-30	.032	2460.088	0	41	41	0	42	41	41+	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF760K15V0 B0, B1, ETC.(REF. 7, 016-016 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	2.35312	3.06E-30	.032	2701.504	0	43	43	0	44	43	43+	75	66	7
49	2.37072	9.51E-31	.032	2953.982	0	45	45	0	46	45	45+	75	66	7
50	2.38833	2.80E-31	.032	3217.481	0	47	47	0	48	47	47+	75	66	7
51	2.40594	7.80E-32	.032	3491.957	0	49	49	0	50	49	49+	75	66	7
52	2.42355	2.06E-32	.032	3777.365	0	51	51	0	52	51	51+	75	66	7
53	2.44118	5.13E-33	.032	4073.659	0	53	53	0	54	53	53+	75	66	7
54	3.96108	1.00E-2[illegible]	.050	0.000	0	1	1	0	0	1	1-	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K15VO   BC, B1, ETC., REF. 7,   O16-O16 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	12.29178	2.22E-26	.048	3.961	0	2	3	0	1	1	SF	75	66	7
2	14.16858	2.43E-25	.045	2.084	0	2	3	0	2	1	SG	75	66	7
3	16.25289	1.04E-25	.045	2.084	0	3	3	0	2	1	SH	75	66	7
4	23.86295	6.28E-26	.045	18.337	0	4	5	0	3	3	SF	75	66	7
5	25.81252	3.96E-25	.044	16.388	0	4	5	0	4	3	SG	75	66	7
6	27.82411	1.37E-25	.044	16.388	0	5	5	0	4	3	SH	75	66	7
7	35.39530	9.10E-26	.043	44.212	0	6	7	0	5	5	SF	75	66	7
8	37.38305	4.91E-25	.042	42.224	0	6	7	0	6	5	SG	75	66	7
9	39.35655	1.54E-25	.042	42.224	0	7	7	0	6	5	SH	75	66	7
10	46.91156	1.04E-26	.042	81.581	0	8	9	0	7	7	SF	75	66	7
11	48.92748	5.22E-25	.041	79.565	0	8	9	0	8	7	SG	75	66	7
12	50.87292	1.56E-25	.041	79.565	0	9	9	0	8	7	SH	75	66	7
13	58.41563	1.03E-25	.041	130.438	0	10	11	0	9	9	SF	75	66	7
14	60.45539	4.95E-25	.040	128.398	0	10	11	0	10	9	SG	75	66	7
15	62.37713	1.43E-25	.040	128.398	0	11	11	0	10	9	SH	75	66	7
16	69.93770	9.19E-26	.041	190.775	0	12	13	0	11	11	SF	75	66	7
17	71.96913	4.28E-25	.039	188.714	0	12	13	0	12	11	SG	75	66	7
18	73.86939	1.21E-25	.039	188.714	0	13	13	0	12	11	SH	75	66	7
19	81.38685	7.48E-26	.038	262.583	0	14	15	0	13	13	SF	75	66	7
20	83.46666	3.41E-25	.038	260.501	0	14	15	0	14	13	SG	75	66	7
21	85.34874	9.46E-26	.038	260.801	0	15	15	0	14	13	SH	75	66	7
22	92.85169	5.62E-26	.036	345.850	0	16	17	0	15	15	SF	75	66	7
23	94.95307	2.52E-25	.034	343.748	0	16	17	0	16	15	SG	75	66	7
24	96.81382	6.91E-26	.034	343.748	0	17	17	0	16	15	SH	75	66	7
25	104.30063	3.92E-26	.037	440.562	0	18	19	0	17	17	SF	75	66	7
26	106.42105	1.74E-25	.036	438.442	0	18	19	0	18	17	SG	75	66	7
27	108.26304	4.72E-26	.036	438.442	0	19	19	0	18	17	SH	75	66	7
28	115.73199	2.56E-26	.036	546.705	0	20	21	0	19	19	SF	75	66	7
29	117.87106	1.12E-25	.035	544.566	0	20	21	0	20	19	SG	75	66	7
30	119.69469	3.02E-26	.035	544.566	0	21	21	0	20	19	SH	75	66	7
31	127.14400	1.56E-26	.035	664.261	0	22	23	0	21	21	SF	75	66	7
32	129.30146	6.79E-26	.035	662.103	0	22	23	0	22	21	SG	75	66	7
33	131.10704	1.81E-26	.035	662.103	0	23	23	0	22	21	SH	75	66	7
34	138.53489	8.90E-27	.035	793.210	0	24	25	0	23	23	SF	75	66	7
35	140.71053	3.86E-26	.032	791.034	0	24	25	0	24	23	SG	75	66	7
36	142.49829	1.02E-26	.032	791.034	0	25	25	0	24	23	SH	75	66	7
37	149.90285	4.78E-27	.032	933.533	0	26	27	0	25	25	SF	75	66	7
38	152.09653	2.06E-26	.032	931.339	0	26	27	0	26	25	SG	75	66	7
39	153.86664	5.44E-27	.032	931.339	0	27	27	0	26	25	SH	75	66	7
40	161.24605	2.41E-27	.032	1085.206	0	28	29	0	27	27	SF	75	66	7
41	163.45765	1.03E-26	.032	1082.994	0	28	29	0	28	27	SG	75	66	7
42	165.21027	2.72E-27	.032	1082.994	0	29	29	0	28	27	SH	75	66	7
43	172.56267	1.15E-27	.032	1248.204	0	30	31	0	29	29	SF	75	66	7
44	174.79210	4.89E-27	.032	1245.975	0	30	31	0	30	29	SG	75	66	7
45	176.52734	1.28E-27	.032	1245.975	0	31	31	0	30	29	SH	75	66	7
46	183.85086	5.13E-28	.032	1422.802	0	32	33	0	31	31	SF	75	66	7
47	186.09807	2.18E-27	.032	1420.255	0	32	33	0	32	31	SG	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K15VO 80, 81, ETC.: REF. 7, O16-O16 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	187.81602	5.71E-28	.032	1420.255	0	33	33	0	32	31	SM	75	66	7
49	195.10679	2.17E-28	.032	1608.071	0	34	35	0	33	33	SF	75	66	7
50	197.37371	9.19E-28	.032	1605.806	0	34	35	0	34	33	SQ	75	66	7
51	199.07447	2.40E-28	.032	1605.804	0	35	35	0	34	33	SM	75	66	7
52	206.33461	8.63E-29	.032	1804.881	0	36	37	0	35	35	SF	75	66	7
53	208.61722	3.65E-28	.032	1802.598	0	36	37	0	36	35	SQ	75	66	7
54	210.30084	9.50E-29	.032	1802.598	0	37	37	0	36	35	SM	75	66	7
55	217.52647	3.25E-29	.032	2012.899	0	38	39	0	37	37	SF	75	66	7
56	219.82673	1.37E-28	.032	2010.599	0	38	39	0	38	37	SQ	75	66	7
57	221.49328	3.56E-29	.032	2010.599	0	39	39	0	38	37	SM	75	66	7
58	228.68253	1.15E-29	.032	2232.092	0	40	41	0	39	39	SF	75	66	7
59	231.00042	4.86E-29	.032	2229.774	0	40	41	0	40	39	SQ	75	66	7
60	232.64995	1.26E-29	.032	2229.774	0	41	41	0	40	39	SM	75	66	7
61	239.80093	3.88E-30	.032	2462.424	0	42	43	0	41	41	SF	75	66	7
62	242.13644	1.63E-29	.032	2460.088	0	42	43	0	42	41	SQ	75	66	7
63	243.76899	4.21E-30	.032	2460.088	0	43	43	0	42	41	SM	75	66	7
64	250.87982	1.23E-30	.032	2703.857	0	44	45	0	43	43	SF	75	66	7
65	253.23294	5.17E-30	.032	2701.504	0	44	45	0	44	43	SQ	75	66	7
66	254.64855	1.33E-30	.032	2701.504	0	45	45	0	44	43	SM	75	66	7
67	261.91735	3.70E-31	.032	2956.353	0	46	47	0	45	45	SF	75	66	7
68	264.28807	1.55E-30	.032	2953.982	0	46	47	0	46	45	SQ	75	66	7
69	265.88678	3.99E-31	.032	2953.982	0	47	47	0	46	45	SM	75	66	7
70	272.91166	1.05E-31	.032	3219.869	0	48	49	0	47	47	SF	75	66	7
71	275.29999	4.40E-31	.032	3217.481	0	48	49	0	48	47	SQ	75	66	7
72	276.88182	1.13E-31	.032	3217.481	0	49	49	0	48	47	SM	75	66	7
73	283.86090	2.83E-32	.032	3494.362	0	50	51	0	49	49	SF	75	66	7
74	286.26684	1.18E-31	.032	3491.957	0	50	51	0	50	49	SQ	75	66	7
75	287.83183	3.04E-32	.032	3491.957	0	51	51	0	50	49	SM	75	66	7
76	294.76322	7.20E-33	.032	3779.788	0	52	53	0	51	51	SF	75	66	7
77	297.18677	3.01E-32	.032	3777.365	0	52	53	0	52	51	SQ	75	66	7
78	298.73494	7.72E-33	.032	3777.365	0	53	53	0	52	51	SM	75	66	7
79	305.61676	1.74E-33	.032	4076.100	0	54	55	0	53	53	SF	75	66	7
80	308.05794	7.25E-33	.032	4073.659	0	54	55	0	54	53	SQ	75	66	7
81	309.58931	1.86E-33	.032	4073.659	0	55	55	0	54	53	SM	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF76CK25V0 B0, B1, ETC.) REF. 7, O16-O18 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	0.00000	0.00E0	.050	0.000	0	0	0	0	1	0	0+	75	68	7
2	0.00000	0.00E0	.050	0.000	0	0	0	0	-1	0	0-	75	68	7
3	1.68274	4.96E-32	.032	2107.907	0	39	39	0	38	39	39-	75	68	7
4	1.69084	8.12E-32	.032	2003.007	0	38	38	0	37	38	38-	75	68	7
5	1.69895	1.31E-31	.032	1900.747	0	37	37	0	36	37	37-	75	68	7
6	1.70707	2.09E-31	.032	1801.129	0	36	36	0	35	36	36-	75	68	7
7	1.71520	3.29E-31	.032	1704.159	0	35	35	0	34	35	35-	75	68	7
8	1.72335	5.11E-31	.032	1609.839	0	34	34	0	33	34	34-	75	68	7
9	1.73150	7.82E-31	.032	1518.173	0	33	33	0	32	33	33-	75	68	7
10	1.73968	1.18E-30	.032	1429.165	0	32	32	0	31	32	32-	75	68	7
11	1.74787	1.76E-30	.032	1342.818	0	31	31	0	30	31	31-	75	68	7
12	1.75608	2.58E-30	.032	1259.136	0	30	30	0	29	30	30-	75	68	7
13	1.76431	3.73E-30	.032	1178.121	0	29	29	0	28	29	29-	75	68	7
14	1.77256	5.33E-30	.032	1099.777	0	28	28	0	27	28	28-	75	68	7
15	1.78084	7.49E-30	.032	1024.107	0	27	27	0	26	27	27-	75	68	7
16	1.78914	1.04E-29	.032	951.113	0	26	26	0	25	26	26-	75	68	7
17	1.79748	1.42E-29	.032	880.799	0	25	25	0	24	25	25-	75	68	7
18	1.80586	1.91E-29	.035	813.167	0	24	24	0	23	24	24-	75	68	7
19	1.81428	2.54E-29	.038	748.219	0	23	23	0	22	23	23-	75	68	7
20	1.82275	3.32E-29	.037	685.959	0	22	22	0	21	22	22-	75	68	7
21	1.83127	4.28E-29	.035	626.388	0	21	21	0	20	21	21-	75	68	7
22	1.83986	5.43E-29	.036	569.509	0	20	20	0	19	20	20-	75	68	7
23	1.84852	6.78E-29	.037	515.324	0	19	19	0	18	19	19-	75	68	7
24	1.85727	8.34E-29	.038	463.835	0	18	18	0	17	18	18-	75	68	7
25	1.86611	1.01E-28	.038	415.043	0	17	17	0	16	17	17-	75	68	7
26	1.87509	1.20E-28	.038	368.952	0	16	16	0	15	16	16-	75	68	7
27	1.88420	1.41E-28	.038	325.562	0	15	15	0	14	15	15-	75	68	7
28	1.89204	5.40E-29	.045	2.633	0	1	1	0	2	1	1+	75	68	7
29	1.89350	1.62E-28	.039	284.875	0	14	14	0	13	14	14-	75	68	7
30	1.90302	1.83E-28	.039	246.893	0	13	13	0	12	13	13-	75	68	7
31	1.91282	2.03E-28	.040	211.617	0	12	12	0	11	12	12-	75	68	7
32	1.92298	2.21E-28	.041	179.048	0	11	11	0	10	11	11-	75	68	7
33	1.93133	1.03E-28	.047	8.025	0	2	2	0	3	2	2+	75	68	7
34	1.93361	2.36E-28	.042	149.187	0	10	10	0	9	10	10-	75	68	7
35	1.94488	2.46E-28	.043	122.036	0	9	9	0	8	9	9-	75	68	7
36	1.95657	1.48E-28	.044	16.146	0	3	3	0	4	3	3+	75	68	7
37	1.95708	2.50E-28	.044	97.595	0	8	8	0	7	8	8-	75	68	7
38	1.97052	2.48E-28	.044	75.865	0	7	7	0	6	7	7-	75	68	7
39	1.97549	1.87E-28	.043	26.989	0	4	4	0	5	4	4+	75	68	7
40	1.98602	2.39E-28	.044	56.845	0	6	6	0	5	6	6-	75	68	7
41	1.99103	2.19E-28	.042	40.850	0	5	5	0	6	5	5+	75	68	7
42	2.00455	2.44E-28	.041	56.827	0	6	6	0	7	6	6+	75	68	7
43	2.00491	2.21E-28	.044	40.536	0	5	5	0	4	5	5-	75	68	7
44	2.01677	2.61E-28	.041	75.819	0	7	7	0	8	7	7+	75	68	7
45	2.02811	2.69E-28	.041	97.824	0	8	8	0	9	8	8+	75	68	7
46	2.03011	1.95E-28	.045	26.934	0	4	4	0	3	4	4-	75	68	7
47	2.03881	2.71E-28	.040	121.942	0	9	9	0	10	9	9+	75	68	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT

AF760K25V0 80, 81, ETC.) REF. 7, O16-O18 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	2.04904	2.65E-28	.039	149.072	0	10	10	0	11	10	10+	75	68	7
49	2.05892	2.54E-28	.039	178.912	0	11	11	0	12	11	11+	75	68	7
50	2.06853	2.38E-28	.039	211.461	0	12	12	0	13	12	12+	75	68	7
51	2.06938	1.61E-28	.047	16.033	0	3	3	0	2	3	3-	75	68	7
52	2.07792	2.18E-28	.038	246.718	0	13	13	0	14	13	13+	75	68	7
53	2.08715	1.97E-28	.036	284.681	0	14	14	0	15	14	14+	75	68	7
54	2.09623	1.74E-28	.034	325.350	0	15	15	0	16	15	15+	75	68	7
55	2.10519	1.52E-28	.035	368.722	0	16	16	0	17	16	16+	75	68	7
56	2.11406	1.30E-28	.036	414.795	0	17	17	0	18	17	17+	75	68	7
57	2.12285	1.09E-28	.036	463.569	0	18	18	0	19	18	18+	75	68	7
58	2.13158	9.03E-29	.035	515.041	0	19	19	0	20	19	19+	75	68	7
59	2.14024	7.35E-29	.035	569.208	0	20	20	0	21	20	20+	75	68	7
60	2.14886	5.90E-29	.035	626.070	0	21	21	0	22	21	21+	75	68	7
61	2.15239	1.18E-28	.048	7.804	0	2	2	0	1	2	2-	75	68	7
62	2.15744	4.66E-29	.034	685.624	0	22	22	0	23	22	22+	75	68	7
63	2.16598	3.62E-29	.032	747.867	0	23	23	0	24	23	23+	75	68	7
64	2.17450	2.78E-29	.032	812.798	0	24	24	0	25	24	24+	75	68	7
65	2.18298	2.10E-29	.032	880.413	0	25	25	0	26	25	25+	75	68	7
66	2.19145	1.56E-29	.032	950.711	0	26	26	0	27	26	26+	75	68	7
67	2.19989	1.14E-29	.032	1023.688	0	27	27	0	28	27	27+	75	68	7
68	2.20832	8.28E-30	.032	1099.341	0	28	28	0	29	28	28+	75	68	7
69	2.21674	5.90E-30	.032	1177.668	0	29	29	0	30	29	29+	75	68	7
70	2.22514	4.15E-30	.032	1258.667	0	30	30	0	31	30	30+	75	68	7
71	2.23353	2.87E-30	.032	1342.332	0	31	31	0	32	31	31+	75	68	7
72	2.24192	1.96E-30	.032	1428.663	0	32	32	0	33	32	32+	75	68	7
73	2.25030	1.32E-30	.032	1517.654	0	33	33	0	34	33	33+	75	68	7
74	2.25867	8.79E-31	.032	1609.303	0	34	34	0	35	34	34+	75	68	7
75	2.26704	5.76E-31	.032	1703.607	0	35	35	0	36	35	35+	75	68	7
76	2.27540	3.72E-31	.032	1800.561	0	36	36	0	37	36	36+	75	68	7
77	2.28377	2.38E-31	.032	1900.162	0	37	37	0	38	37	37+	75	68	7
78	2.29213	1.49E-31	.032	2002.406	0	38	38	0	39	38	38+	75	68	7
79	2.30049	9.28E-32	.032	2107.289	0	39	39	0	40	39	39+	75	68	7
80	3.96140	1.94E-28	.050	0.563	0	1	1	0	0	1	1-	75	68	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K25V0   80, 81, ETC.; REF. 7,   016-018 SUBMM LINES,   KRUPENIE WIDTHS,   V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	0.00000	0.00E0	.050	0.000	0	1	2	0	0	0	SF	75	68	7
2	7.80360	2.91E-28	.070	0.000	0	1	2	0	1	0	SG	75	68	7
3	9.95599	1.67E-28	.050	0.000	0	2	8	0	1	0	SH	75	68	7
4	11.50856	4.25E-29	.048	4.525	0	2	3	0	1	1	SF	75	68	7
5	13.40060	4.72E-28	.045	2.633	0	2	3	0	2	1	SG	75	68	7
6	15.46998	2.05E-28	.045	2.633	0	3	3	0	2	1	SH	75	68	7
7	16.97828	8.41E-29	.048	9.956	0	3	4	0	2	2	SF	75	68	7
8	18.90961	6.35E-28	.047	8.025	0	3	4	0	3	2	SG	75	68	7
9	20.93973	2.40E-28	.047	8.025	0	4	4	0	3	2	SH	75	68	7
10	22.43321	1.22E-28	.045	18.103	0	4	5	0	3	3	SF	75	68	7
11	24.38978	7.75E-28	.044	16.146	0	4	8	0	4	3	SG	75	68	7
12	26.39469	2.69E-28	.044	16.146	0	5	5	0	4	3	SH	75	68	7
13	27.88090	1.53E-28	.044	28.964	0	5	8	0	4	4	SF	75	68	7
14	29.85639	8.87E-28	.043	26.989	0	5	8	0	5	4	SG	75	68	7
15	31.84241	2.92E-28	.043	26.989	0	6	6	0	5	4	SH	75	68	7
16	33.32407	1.78E-28	.043	42.541	0	6	7	0	5	5	SF	75	68	7
17	35.31509	9.69E-28	.042	40.550	0	6	7	0	6	5	SG	75	68	7
18	37.28562	3.06E-28	.042	40.550	0	7	7	0	6	5	SH	75	68	7
19	38.76386	1.96E-28	.043	58.831	0	7	8	0	6	6	SF	75	68	7
20	40.76842	1.02E-27	.041	56.827	0	7	8	0	7	6	SG	75	68	7
21	42.72546	3.13E-28	.041	56.827	0	8	8	0	7	6	SH	75	68	7
22	44.20080	2.07E-28	.042	77.835	0	8	9	0	7	7	SF	75	68	7
23	46.21758	1.04E-27	.041	75.819	0	8	9	0	8	7	SG	75	68	7
24	48.16245	3.12E-28	.041	73.819	0	9	9	0	8	7	SH	75	68	7
25	49.63509	2.11E-28	.042	99.852	0	9	10	0	8	8	SF	75	68	7
26	51.66320	1.03E-27	.041	97.524	0	9	10	0	9	8	SG	75	68	7
27	53.59681	3.04E-28	.041	97.824	0	10	10	0	9	8	SH	75	68	7
28	55.06678	2.08E-28	.041	123.981	0	10	11	0	9	9	SF	75	68	7
29	57.10558	1.00E-27	.040	121.942	0	10	11	0	10	9	SG	75	68	7
30	59.02856	2.90E-28	.040	121.942	0	11	11	0	10	9	SH	75	68	7
31	60.49582	2.01E-28	.041	151.121	0	11	18	0	10	10	SF	75	68	7
32	62.54486	9.49E-28	.039	149.072	0	11	18	0	11	10	SG	75	68	7
33	64.45768	2.72E-28	.039	149.072	0	12	18	0	11	10	SH	75	68	7
34	65.92213	1.89E-28	.041	180.971	0	12	13	0	11	11	SF	75	68	7
35	67.98106	8.82E-28	.039	178.912	0	12	13	0	12	11	SG	75	68	7
36	69.88407	2.50E-28	.039	178.912	0	13	13	0	12	11	SH	75	68	7
37	71.34558	1.74E-28	.040	213.530	0	13	14	0	12	12	SF	75	68	7
38	73.41411	8.03E-28	.039	211.461	0	13	14	0	13	12	SG	75	58	7
39	75.30761	2.25E-28	.039	211.461	0	14	14	0	13	12	SH	75	68	7
40	76.76602	1.57E-28	.038	248.796	0	14	15	0	13	13	SF	75	68	7
41	78.84394	7.18E-28	.038	246.718	0	14	15	0	14	13	SG	75	68	7
42	80.72815	2.00E-28	.038	246.718	0	15	15	0	14	13	SH	75	68	7
43	82.18328	1.39E-28	.038	286.769	0	15	16	0	14	14	SF	75	68	7
44	84.27043	6.30E-28	.036	284.681	0	15	16	0	15	14	SG	75	68	7
45	86.14551	1.74E-28	.036	284.681	0	16	16	0	15	14	SH	75	68	7
46	87.59720	1.21E-28	.036	327.446	0	16	17	0	15	15	SF	75	68	7
47	89.69343	5.44E-28	.034	325.35[illegible]	0	16	17	0	16	15	SG	75	68	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K25VC   B0, B1, ETC.: REF. 7,   O16-O18 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	91.55954	1.49E-28	.034	325.35[illegible]	0	17	17	0	16	15	SH	75	68	7
49	93.00758	1.03E-28	.037	370.827	0	17	18	0	16	16	SF	75	68	7
50	95.11278	4.61E-28	.035	368.722	0	17	16	0	17	16	SG	75	68	7
51	96.97004	1.26E-28	.035	368.722	0	18	18	0	17	16	SH	75	68	7
52	98.41425	8.67E-29	.037	416.909	0	18	19	0	17	17	SF	75	68	7
53	100.52832	3.85E-28	.036	414.795	0	18	19	0	18	17	SG	75	68	7
54	102.37684	1.05E-28	.036	414.795	0	19	19	0	18	17	SH	75	68	7
55	103.81702	7.16E-29	.037	465.692	0	19	20	0	18	18	SF	75	68	7
56	105.93987	3.17E-28	.036	463.569	0	19	20	0	19	18	SG	75	68	7
57	107.77973	8.56E-29	.036	463.569	0	20	2[illegible]	0	19	18	SH	75	68	7
58	109.21568	5.82E-29	.036	517.172	0	20	21	0	19	19	SF	75	68	7
59	111.34725	2.56E-28	.03[illegible]	515.041	0	20	21	0	20	19	SG	75	68	7
60	113.17852	6.90E-29	.035	515.041	0	21	21	0	20	19	SH	75	68	7
61	114.61004	4.65E-29	.036	571.349	0	21	22	0	20	20	SF	75	68	7
62	116.75028	2.04E-28	.035	569.208	0	21	22	0	21	20	SG	75	68	7
63	118.57303	5.47E-29	.035	569.208	0	22	22	0	21	20	SH	75	68	7
64	119.99390	3.66E-29	.035	628.219	0	22	23	0	21	21	SF	75	68	7
65	122.14877	1.60E-28	.035	626.070	0	22	23	0	22	21	SG	75	68	7
66	123.96305	4.28E-29	.035	626.070	0	23	23	0	22	21	SH	75	68	7
67	125.38508	2.84E-29	.036	687.782	0	23	24	0	22	22	SF	75	68	7
68	127.54252	1.24E-28	.034	685.624	0	23	24	0	23	22	SG	75	68	7
69	129.34838	3.30E-29	.034	685.624	0	24	24	0	23	22	SH	75	68	7
70	130.76535	2.17E-29	.035	750.033	0	24	25	0	23	23	SF	75	68	7
71	132.93134	9.41E-29	.032	747.867	0	24	28	0	24	23	SG	75	68	7
72	134.72882	2.50E-29	.032	747.867	0	25	28	0	24	23	SH	75	68	7
73	136.14053	1.63E-29	.034	814.972	0	25	26	0	24	24	SF	75	68	7
74	138.31503	7.06E-29	.032	812.798	0	25	26	0	25	24	SG	75	68	7
75	140.10417	1.87E-29	.032	812.798	0	26	26	0	25	24	SH	75	68	7
76	141.51041	1.21E-29	.032	882.896	0	26	27	0	25	25	SF	75	68	7
77	143.69339	5.22E-29	.032	880.413	0	26	27	0	26	25	SG	75	68	7
78	145.47423	1.38E-29	.032	880.413	0	27	27	0	26	25	SH	75	68	7
79	146.87478	8.85E-30	.032	952.902	0	27	28	0	26	26	SF	75	68	7
80	149.06623	3.81E-29	.032	950.711	0	27	28	0	27	26	SG	75	68	7
81	150.83879	1.01E-29	.032	950.711	0	28	28	0	27	26	SH	75	68	7
82	152.23345	6.37E-30	.032	1025.887	0	28	29	0	27	27	SF	75	68	7
83	154.03335	2.74E-29	.032	1023.688	0	28	29	0	28	27	SG	75	68	7
84	156.19765	7.21E-30	.032	1023.688	0	29	29	0	28	27	SH	75	68	7
85	157.58621	4.52E-30	.032	1101.849	0	29	38	0	28	28	SF	75	68	7
86	159.79453	1.94E-29	.032	1099.341	0	29	30	0	29	28	SG	75	68	7
87	161.55061	5.10E-30	.032	1099.341	0	30	30	0	29	28	SH	75	68	7
88	162.93286	3.17E-30	.032	1179.885	0	30	31	0	29	29	SF	75	68	7
89	165.14960	1.35E-29	.032	1177.668	0	30	31	0	30	29	SG	75	68	7
90	166.89746	3.56E-30	.032	1177.668	0	31	31	0	30	29	SH	75	68	7
91	168.27319	2.19E-30	.032	1260.892	0	31	32	0	30	30	SF	75	68	7
92	170.49833	9.33E-30	.032	1258.667	0	31	32	0	31	30	SG	75	68	7
93	172.23801	2.45E-30	.032	1258.667	0	32	32	0	31	30	SH	75	68	7
94	173.60699	1.49E-30	.032	1344.866	0	32	33	0	31	31	SF	75	68	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K25V0 80, 81, ETC., REF. 7, O16-O18 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
95	175.84053	6.34E-30	.032	1342.332	0	32	33	0	32	31	SQ	75	68	7
96	177.57203	1.66E-30	.032	1342.332	0	33	33	0	32	31	SH	75	68	7
97	178.93407	9.99E-31	.032	1430.905	0	33	34	0	32	32	SF	75	68	7
98	181.17599	4.25E-30	.032	1428.663	0	33	34	0	33	32	SQ	75	68	7
99	182.89934	1.11E-30	.032	1428.663	0	34	34	0	33	32	SH	75	68	7
100	184.25422	6.61E-31	.032	1519.904	0	34	38	0	33	33	SF	76	68	7
101	186.50451	2.81E-30	.032	1517.654	0	34	38	0	34	33	SQ	75	68	7
102	188.21971	7.33E-31	.032	1517.654	0	35	38	0	34	33	SH	75	68	7
103	189.56722	4.32E-31	.032	1611.862	0	38	36	0	34	34	SF	75	68	7
104	191.82589	1.83E-30	.032	1609.303	0	35	38	0	35	34	SG	75	68	7
105	193.53296	4.77E-31	.032	1609.303	0	36	38	0	35	34	SH	75	68	7
106	194.87289	2.78E-31	.032	1705.874	0	36	37	0	35	35	SF	75	68	7
107	197.13992	1.18E-30	.032	1703.607	0	36	37	0	36	35	SQ	75	68	7
108	198.83887	3.07E-31	.032	1703.607	0	37	37	0	36	35	SH	75	68	7
109	200.17100	1.77E-31	.032	1802.836	0	37	38	0	36	36	SF	75	68	7
110	202.44640	7.47E-31	.032	1800.861	0	37	38	0	37	36	SQ	75	68	7
111	204.13724	1.94E-31	.032	1800.861	0	38	38	0	37	36	SH	75	68	7
112	205.46136	1.11E-31	.032	1902.446	0	38	39	0	37	37	SF	75	68	7
113	207.74513	4.68E-31	.032	1900.162	0	38	39	0	38	37	SQ	75	68	7
114	209.42786	1.21E-31	.032	1900.162	0	39	39	0	38	37	SH	75	68	7
115	210.74376	6.84E-32	.032	2004.698	0	39	40	0	38	38	SF	75	68	7
116	213.03589	2.89E-31	.032	2002.406	0	39	40	0	39	38	SQ	75	68	7
117	214.71053	7.49E-32	.032	2002.406	0	40	40	0	39	38	SH	75	68	7
118	216.01800	4.17E-32	.032	2109.890	0	40	41	0	39	39	SF	75	68	7
119	218.31849	1.76E-31	.032	2107.209	0	40	41	0	40	39	SQ	75	68	7
120	219.98504	4.56E-32	.032	2107.209	0	41	41	0	40	39	SH	75	68	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF760K35v0 80, 81, ETC.: REF. 7, O18-O18 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K'' ID	DATE	ISO	MO
1	1.59501	7.20E-38	.032	3626.054	0	53	53	0	52	53 53-	75	88	7
2	1.60999	2.55E-37	.032	3362.098	0	51	51	0	50	51 51-	75	88	7
3	1.62498	8.58E-37	.032	3107.879	0	49	49	0	48	49 49-	75	88	7
4	1.63999	2.75E-36	.032	2863.432	0	47	47	0	46	47 47-	75	88	7
5	1.65502	8.40E-36	.032	2628.794	0	45	45	0	44	45 45-	75	88	7
6	1.67007	2.44E-35	.032	2403.998	0	43	43	0	42	43 43-	75	88	7
7	1.68514	6.73E-35	.032	2189.078	0	41	41	0	40	41 41-	75	88	7
8	1.70025	1.77E-34	.032	1984.065	0	39	39	0	38	39 39-	75	88	7
9	1.71539	4.41E-34	.032	1788.989	0	37	37	0	36	37 37-	75	88	7
10	1.73056	1.04E-33	.032	1603.877	0	35	35	0	34	35 35-	75	88	7
11	1.74579	2.35E-33	.032	1428.758	0	33	33	0	32	33 33-	75	88	7
12	1.76107	5.01E-33	.032	1263.655	0	31	31	0	30	31 31-	75	88	7
13	1.77642	1.01E-32	.032	1108.594	0	29	29	0	28	29 29-	75	88	7
14	1.79186	1.95E-32	.032	963.597	0	27	27	0	26	27 27-	75	88	7
15	1.80740	3.54E-32	.032	828.684	0	25	25	0	24	25 25-	75	88	7
16	1.82307	6.08E-32	.038	703.875	0	23	23	0	22	23 23-	75	88	7
17	1.83890	9.89E-32	.035	589.188	0	21	21	0	20	21 21-	75	88	7
18	1.85495	1.52E-31	.037	484.641	0	19	19	0	18	19 19-	75	88	7
19	1.87130	2.19E-31	.038	390.246	0	17	17	0	16	17 17-	75	88	7
20	1.88[illegible]06	2.97E-31	.038	306.019	0	15	15	0	14	15 15-	75	88	7
21	1.90543	3.77E-31	.0[illegible]9	231.971	0	13	13	0	12	13 13-	75	88	7
22	1.90932	1.05E-31	.045	2.052	0	1	1	0	2	1 1+	75	88	7
23	1.92376	4.46E-31	.041	168.112	0	11	11	0	10	11 11-	75	88	7
24	1.94370	4.87E-31	.043	114.452	0	9	9	0	8	9 9-	75	88	7
25	1.96468	2.87E-31	.044	14.777	0	3	3	0	4	3 3+	75	88	7
26	1.96676	4.84E-31	.044	70.995	0	7	7	0	6	7 7-	75	88	7
27	1.99509	4.27E-31	.042	37.747	0	5	5	0	6	5 5+	75	88	7
28	1.99710	4.25E-31	.044	37.745	0	5	5	0	4	5 5-	75	88	7
29	2.0[illegible]826	5.11E-31	.041	70.944	0	7	7	0	8	7 7+	75	88	7
30	2.0[illegible]233	5.37E-31	.040	114.357	0	9	9	0	10	[illegible] 9+	75	88	7
31	2.0[illegible]242	3.04E-31	.047	14.689	0	3	3	0	2	3 3-	75	88	7
32	2.0[illegible]682	5.11E-31	.039	167.979	0	11	11	0	12	11 11+	75	88	7
33	2.07437	4.48E-31	.038	231.802	0	13	13	0	14	13 13+	75	88	7
34	2.09134	3.65E-31	.034	305.816	0	15	15	0	16	15 15+	75	88	7
35	2.10793	2.78E-31	.036	390.010	0	17	17	0	18	17 17+	75	88	7
36	2.12425	1.99E-31	.035	484.371	0	19	19	0	20	19 19+	75	88	7
37	2.14038	1.34E-31	.035	588.887	0	21	21	0	22	21 21+	75	88	7
38	2.15637	8.52E-32	.032	703.542	0	23	23	0	24	23 23+	75	88	7
39	2.17225	5.12E-32	.032	828.319	0	25	25	0	26	25 25+	75	88	7
40	2.18806	2.91E-32	.032	963.201	0	27	27	0	28	27 27+	75	88	7
41	2.20382	1.56E-32	.032	1108.167	0	29	29	0	30	29 29+	75	88	7
42	2.21953	7.97E-33	.032	1263.197	0	31	31	0	32	31 31+	75	88	7
43	2.23522	3.85E-33	.032	1[illegible]8.268	0	33	33	0	34	33 33+	75	88	7
44	2.25088	1.77E-33	.032	1603.357	0	35	35	0	36	35 35+	75	88	7
45	2.26653	7.70E-34	.032	1788.438	0	37	37	0	38	37 37+	75	88	7
46	2.28217	3.19E-34	.032	1983.483	0	39	39	0	40	39 39+	75	88	7
47	2.29782	1.25E-34	.032	2188.466	0	41	41	0	42	41 41+	75	88	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF760K35V0   80, 81, ETC.; REF. 7, O18-O18 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	2.31346	4.69E-35	.032	2403.355	0	43	43	0	44	43	43+	75	88	7
49	2.32911	1.67E-35	.032	2628.120	0	45	45	0	46	45	45+	75	88	7
50	2.34477	5.64E-36	.032	2862.727	0	47	47	0	48	47	47+	75	88	7
51	2.36044	1.81E-36	.032	3107.143	0	49	49	0	50	49	49+	75	88	7
52	2.37612	5.56E-37	.032	3361.332	0	51	51	0	52	51	51+	75	88	7
53	2.39182	1.62E-37	.032	3625.287	0	53	53	0	54	53	53+	75	88	7
54	3.96171	3.73E-31	.050	0.000	0	1	1	0	0	1	1-	75	88	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K35V0   B0, B1, ETC.: REF. 7, O18-O18 SUBMM LINES, KNUPENIE WIDTHS, V = 0

	FREG	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	10.72714	8.00E-32	.048	3.962	0	2	3	0	1	1	SF	75	88	7
2	12.63646	9.07E-31	.045	2.052	0	2	1	0	2	1	SG	75	88	7
3	14.68888	4.00E-31	.045	2.052	0	3	3	0	2	1	SH	75	88	7
4	21.00418	2.32E-31	.045	16.741	0	4	5	0	3	3	SF	75	88	7
5	22.96886	1.50E-30	.044	14.777	0	4	5	0	4	3	SG	75	88	7
6	24.96596	5.26E-31	.044	14.777	0	5	5	0	4	3	SH	75	88	7
7	31.25291	3.45E-31	.043	39.743	0	6	7	0	5	5	SF	75	88	7
8	33.24801	1.89E-30	.042	37.747	0	6	7	0	6	5	SG	75	88	7
9	35.21477	6.01E-31	.042	37.747	0	7	7	0	6	5	SH	75	88	7
10	41.43958	4.05E-31	.042	72.962	0	8	9	0	7	7	SF	75	88	7
11	43.50784	2.05E-30	.041	70.944	0	8	9	0	8	7	SG	75	88	7
12	45.45154	6.18E-31	.041	70.944	0	9	9	0	8	7	SH	75	88	7
13	51.71688	4.15E-31	.041	116.396	0	10	11	0	9	9	SF	75	88	7
14	53.75522	2.00E-30	.040	114.357	0	10	11	0	10	9	SG	75	88	7
15	55.67897	5.83E-31	.040	114.357	0	11	11	0	10	9	SH	75	88	7
16	61.93483	3.83E-31	.041	170.036	0	12	13	0	11	11	SF	75	88	7
17	63.99164	1.79E-30	.039	167.979	0	12	13	0	12	11	SG	75	88	7
18	65.89707	5.10E-31	.039	167.979	0	13	13	0	12	11	SH	75	88	7
19	72.14261	3.25E-31	.038	233.876	0	14	15	0	13	13	SF	75	88	7
20	74.21698	1.49E-30	.038	231.802	0	14	15	0	14	13	SG	75	88	7
21	76.10504	4.16E-31	.038	231.802	0	15	15	0	14	13	SH	75	88	7
22	82.33910	2.56E-[illegible]	.036	307.907	0	16	17	0	15	15	SF	75	88	7
23	84.43045	1.15E-30	.034	305.816	0	16	17	0	16	15	SG	75	88	7
24	86.30175	3.19E-31	.034	305.816	0	17	17	0	16	15	SH	75	88	7
25	92.52303	1.89E-31	.037	392.117	0	18	19	0	17	17	SF	75	88	7
26	94.63096	8.42E-31	.036	390.010	0	18	19	0	18	17	SG	75	88	7
27	96.48591	2.29E-31	.036	390.010	0	19	19	0	18	17	SH	75	88	7
28	102.69304	1.31E-31	.036	486.495	0	20	21	0	19	19	SF	75	88	7
29	104.81729	5.77E-31	.035	484.371	0	20	21	0	20	19	SG	75	88	7
30	106.65619	1.56E-31	.035	484.371	0	21	21	0	20	19	SH	75	88	7
31	112.84773	8.51E-32	.035	591.027	0	22	23	0	21	21	SF	75	88	7
32	114.98811	3.72E-31	.035	588.887	0	22	23	0	22	21	SG	75	88	7
33	116.81117	9.98E-32	.035	588.887	0	23	23	0	22	21	SH	75	88	7
34	122.98568	5.23E-32	.035	705.698	0	24	25	0	23	23	SF	75	88	7
35	125.14205	2.27E-31	.032	703.542	0	24	25	0	24	23	SG	75	88	7
36	126.94945	6.05E-32	.032	703.542	0	25	25	0	24	23	SH	75	88	7
37	133.10546	3.03E-32	.032	830.491	0	26	27	0	25	25	SF	75	88	7
38	135.27771	1.31E-31	.032	828.319	0	26	27	0	26	25	SG	75	88	7
39	137.06957	3.47E-32	.032	828.319	0	27	27	0	26	25	SH	75	88	7
40	143.20562	1.66E-32	.032	965.389	0	28	29	0	27	27	SF	75	88	7
41	145.39368	7.16E-32	.032	963.201	0	28	29	0	28	27	SG	75	88	7
42	147.17021	1.89E-32	.032	963.201	0	29	29	0	28	27	SH	75	88	7
43	153.28470	8.56E-33	.032	1110.371	0	30	31	0	29	29	SF	75	88	7
44	155.48852	3.71E-32	.032	1108.167	0	30	31	0	30	29	SG	75	88	7
45	157.24960	9.75E-33	.032	1108.167	0	31	31	0	30	29	SH	75	88	7
46	163.34126	4.27E-33	.032	1265.416	0	32	33	0	31	31	SF	75	88	7
47	165.56079	1.82E-32	.032	1263.197	0	32	33	0	32	31	SG	75	88	7

MMI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF7K35V0 60, 61, ETC.: REF. 7, 018-018 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	167.30658	4.77E-33	.032	1263.197	0	33	33	0	32	31	SH	75	88	7
49	173.37382	1.99E-33	.032	1430.503	0	34	35	0	33	33	SF	75	88	7
50	175.60903	8.49E-33	.032	1428.268	0	34	35	0	34	33	SQ	75	88	7
51	177.33960	2.22E-33	.032	1428.268	0	35	35	0	34	33	SH	75	88	7
52	183.38092	8.85E-34	.032	1605.608	0	36	37	0	35	35	SF	75	88	7
53	185.63180	3.76E-33	.032	1603.357	0	36	37	0	36	35	SQ	75	88	7
54	187.34718	9.79E-34	.032	1603.357	0	37	37	0	36	35	SH	75	88	7
55	193.36110	3.73E-34	.032	1790.704	0	38	39	0	37	37	SF	75	88	7
56	195.62763	1.58E-33	.032	1788.438	0	35	39	0	38	37	SQ	75	88	7
57	197.32787	4.10E-34	.032	1788.438	0	39	39	0	38	37	SH	75	88	7
58	203.31288	1.49E-34	.032	1985.765	0	40	41	0	39	39	SF	75	88	7
59	205.59506	6.31E-34	.032	1983.483	0	40	41	0	40	39	SQ	75	88	7
60	207.28020	1.64E-34	.032	1983.483	0	41	41	0	40	39	SH	75	88	7
61	213.23481	5.68E-35	.032	2190.764	0	42	43	0	41	41	SF	75	88	7
62	215.53263	2.40E-34	.032	2188.466	0	42	43	0	42	41	SQ	75	88	7
63	217.20270	6.20E-35	.032	2188.466	0	43	43	0	42	41	SH	75	88	7
64	223.12542	2.06E-35	.032	2405.668	0	44	45	0	43	43	SF	75	88	7
65	225.43888	8.65E-35	.032	2403.355	0	44	45	0	44	43	SQ	75	88	7
66	227.09390	2.24E-35	.032	2403.355	0	45	45	0	44	43	SH	75	88	7
67	232.98323	7.08E-36	.032	2630.449	0	46	47	0	45	45	SF	75	88	7
68	235.31234	2.98E-35	.032	2628.120	0	46	47	0	46	45	SQ	75	88	7
69	236.95233	7.68E-36	.032	2628.120	0	47	47	0	46	45	SH	75	88	7
70	242.80677	2.32E-36	.032	2865.072	0	48	49	0	47	47	SF	75	88	7
71	245.15154	9.73E-36	.032	2862.727	0	48	49	0	48	47	SQ	75	88	7
72	246.77652	2.51E-36	.032	2862.727	0	49	49	0	48	47	SH	75	88	7
73	252.59457	7.24E-37	.032	3109.504	0	50	51	0	49	49	SF	75	88	7
74	254.95501	3.03E-36	.032	3107.143	0	50	51	0	50	49	SQ	75	88	7
75	256.56500	7.80E-37	.032	3107.143	0	51	51	0	50	49	SH	75	88	7
76	262.34517	2.15E-37	.032	3363.708	0	52	53	0	51	51	SF	75	88	7
77	264.72129	8.99E-37	.032	3361.332	0	52	53	0	52	51	SQ	75	88	7
78	266.31630	2.31E-37	.032	3361.332	0	53	53	0	52	51	SH	75	88	7
79	272.05709	6.08E-38	.032	3627.649	0	54	55	0	53	53	SF	75	88	7
80	274.44891	2.54E-37	.032	3625.257	0	54	55	0	54	53	SQ	75	88	7
81	276.02896	6.52E-38	.032	3625.257	0	55	55	0	54	53	SH	75	88	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF560K15,1 60, 81, ETC.: REF. 5, 016-016 MICROWAVE LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	1.52311	1.27E-36	.032	5585.860	1	53	53	1	52	53	53-	75	66	7
2	1.54128	5.21E-36	.032	5292.844	1	51	51	1	50	51	51-	75	66	7
3	1.55948	2.02E-35	.032	5010.588	1	49	49	1	48	49	49-	75	66	7
4	1.57770	7.43E-35	.032	4739.137	1	47	47	1	46	47	47-	75	66	7
5	1.59594	2.58E-34	.032	4478.538	1	45	45	1	44	45	45-	75	66	7
6	1.61420	8.50E-34	.032	4228.832	1	43	43	1	42	43	43-	75	66	7
7	1.63250	2.65E-33	.032	3990.062	1	41	41	1	40	41	41-	75	66	7
8	1.65084	7.80E-33	.032	3762.267	1	39	39	1	38	39	39-	75	66	7
9	1.66921	2.17E-32	.032	3545.485	1	37	37	1	36	37	37-	75	66	7
10	1.68764	5.71E-32	.032	3339.751	1	35	35	1	34	35	35-	75	66	7
11	1.70613	1.42E-31	.032	3145.099	1	33	33	1	32	33	33-	75	66	7
12	1.72468	3.33E-31	.032	2961.562	1	31	31	1	30	31	31-	75	66	7
13	1.74332	7.36E-31	.032	2789.170	1	29	29	1	28	29	29-	75	66	7
14	1.76207	1.53E-30	.032	2627.950	1	27	27	1	26	27	27-	75	66	7
15	1.78094	3.01E-30	.032	2477.929	1	25	25	1	24	25	25-	75	66	7
16	1.79998	5.57E-30	.038	2339.133	1	23	23	1	22	23	23-	75	66	7
17	1.81923	9.67E-30	.035	2211.583	1	21	21	1	20	21	21-	75	66	7
18	1.83877	1.58E-29	.037	2095.301	1	19	19	1	18	19	19-	75	66	7
19	1.85869	2.41E-29	.038	1990.305	1	17	17	1	16	17	17-	75	66	7
20	1.87915	3.43E-29	.038	1896.613	1	15	15	1	14	15	15-	75	66	7
21	1.88985	1.42E-29	.045	1558.465	1	1	1	1	2	1	1+	75	66	7
22	1.90041	4.56E-29	.039	1814.239	1	13	13	1	12	13	13-	75	66	7
23	1.92295	5.61E-29	.041	1743.197	1	11	11	1	10	11	11-	75	66	7
24	1.94764	6.33E-29	.043	1683.497	1	9	9	1	8	9	9-	75	66	7
25	1.96204	3.92E-29	.044	1572.612	1	3	3	1	4	3	3+	75	66	7
26	1.97649	6.48E-29	.044	1635.147	1	7	7	1	6	7	7-	75	66	7
27	2.00064	5.80E-29	.042	1598.164	1	5	5	1	6	5	5+	75	66	7
28	2.01509	5.84E-29	.044	1598.149	1	5	5	1	4	5	5-	75	66	7
29	2.02949	6.85E-29	.041	1635.094	1	7	7	1	6	7	7+	75	66	7
30	2.05418	7.06E-29	.040	1683.390	1	9	9	1	10	9	9+	75	66	7
31	2.07672	6.55E-29	.039	1743.043	1	11	11	1	12	11	11+	75	66	7
32	2.08728	4.32E-29	.047	1572.486	1	3	3	1	2	3	3-	75	66	7
33	2.09798	5.56E-29	.038	1814.041	1	13	13	1	14	13	13+	75	66	7
34	2.11844	4.37E-29	.034	1896.373	1	15	15	1	16	15	15+	75	66	7
35	2.13836	3.19E-29	.036	1990.025	1	17	17	1	18	17	17+	75	66	7
36	2.15790	2.17E-29	.035	2094.982	1	19	19	1	20	19	19+	75	66	7
37	2.17715	1.39E-29	.035	2211.225	1	21	21	1	22	21	21+	75	66	7
38	2.19619	8.29E-30	.032	2338.737	1	23	23	1	24	23	23+	75	66	7
39	2.21506	4.66E-30	.032	2477.495	1	25	25	1	26	25	25+	75	66	7
40	2.23381	2.47E-30	.032	2627.478	1	27	27	1	28	27	27+	75	66	7
41	2.25245	1.23E-30	.032	2788.661	1	29	29	1	30	29	29+	75	66	7
42	2.27100	5.78E-31	.032	2961.016	1	31	31	1	32	31	31+	75	66	7
43	2.28949	2.56E-31	.032	3144.516	1	33	33	1	34	33	33+	75	66	7
44	2.30792	1.07E-31	.032	3339.131	1	35	35	1	36	35	35+	75	66	7
45	2.32629	4.22E-32	.032	3544.828	1	37	37	1	38	37	37+	75	66	7
46	2.34463	1.58E-32	.032	3761.573	1	39	39	1	40	39	39+	75	66	7
47	2.36293	5.56E-33	.032	3989.332	1	41	41	1	42	41	41+	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF560K15v1 80, 81, ETC.: REF. 5, O16-O16 MICROWAVE LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	2.38119	1.85E-33	.032	4228.065	1	43	43	1	44	43	43+	75	66	7
49	2.39943	5.85E-34	.032	4477.734	1	45	45	1	46	45	45+	75	66	7
50	2.41765	1.75E-34	.032	4738.297	1	47	47	1	48	47	47+	75	66	7
51	2.43585	4.94E-35	.032	5009.711	1	49	49	1	50	49	49+	75	66	7
52	2.45402	1.32E-35	.032	5291.932	1	51	51	1	52	51	51+	75	66	7
53	2.47218	3.36E-36	.032	5584.911	1	53	53	1	54	53	53+	75	66	7
54	3.97713	5.17E-29	.050	1556.378	1	1	1	1	0	1	1-	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF5K1DV1 BO, B1, ETC.: REF. 5, 016-016 SUBMM LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	12.13118	1.14E-29	.048	1560.355	1	2	3	1	1	1	SF	75	66	7
2	14.02102	1.25E-28	.045	1558.465	1	2	3	1	2	1	SG	75	66	7
3	16.10831	5.38E-29	.045	1558.465	1	3	3	1	2	1	SH	75	66	7
4	23.57570	3.24E-29	.045	1574.874	1	4	5	1	3	3	SF	75	66	7
5	25.53774	2.05E-28	.044	1572.612	1	4	5	1	4	3	SG	75	66	7
6	27.55283	7.08E-29	.044	1572.612	1	5	5	1	4	3	SH	75	66	7
7	34.98245	4.71E-29	.043	1600.164	1	6	7	1	5	5	SF	75	66	7
8	36.98309	2.55E-28	.042	1598.164	1	6	7	1	6	5	SG	75	66	7
9	38.95958	8.01E-29	.042	1598.164	1	7	7	1	6	5	SH	75	66	7
10	46.37341	5.40E-29	.042	1637.123	1	8	9	1	7	7	SF	75	66	7
11	48.40290	2.71E-28	.041	1635.094	1	8	9	1	8	7	SG	75	66	7
12	50.35054	8.09E-29	.041	1635.094	1	9	9	1	8	7	SH	75	66	7
13	57.75231	5.37E-29	.041	1685.444	1	10	11	1	9	9	SF	75	66	7
14	59.80650	2.58E-28	.040	1683.390	1	10	11	1	10	9	SG	75	66	7
15	61.72944	7.45E-29	.040	1683.390	1	11	11	1	10	9	SH	75	66	7
16	69.11929	4.80E-29	.041	1745.120	1	12	13	1	11	11	SF	75	66	7
17	71.19601	2.24E-28	.039	1743.043	1	12	13	1	12	11	SG	75	66	7
18	73.09642	6.32E-29	.039	1743.043	1	13	13	1	12	11	SH	75	66	7
19	80.47340	3.92E-29	.038	1816.139	1	14	15	1	13	13	SF	75	66	7
20	82.57138	1.79E-28	.038	1814.041	1	14	15	1	14	13	SG	75	66	7
21	84.45053	4.97E-29	.038	1814.041	1	15	15	1	14	13	SH	75	66	7
22	91.81322	2.96E-29	.036	1898.492	1	16	17	1	15	15	SF	75	66	7
23	93.93166	1.33E-28	.034	1896.373	1	16	17	1	16	15	SG	75	66	7
24	95.79035	3.65E-29	.034	1896.373	1	17	17	1	16	15	SH	75	66	7
25	103.13716	2.08E-29	.037	1992.164	1	18	19	1	17	17	SF	75	66	7
26	105.27552	9.23E-29	.036	1990.025	1	18	19	1	18	17	SG	75	66	7
27	107.11429	2.50E-29	.036	1990.025	1	19	19	1	18	17	SH	75	66	7
28	114.44353	1.36E-29	.036	2097.140	1	20	21	1	19	19	SF	75	66	7
29	116.60142	5.99E-29	.035	2094.982	1	20	21	1	20	19	SG	75	66	7
30	118.42066	1.61E-29	.035	2094.982	1	21	21	1	20	19	SH	75	66	7
31	125.73056	8.35E-30	.035	2213.402	1	22	23	1	21	21	SF	75	66	7
32	127.90771	3.64E-29	.035	2211.225	1	22	23	1	22	21	SG	75	66	7
33	129.70769	9.73E-30	.035	2211.225	1	23	23	1	22	21	SH	75	66	7
34	136.99447	4.80E-30	.035	2340.933	1	24	25	1	23	23	SF	75	66	7
35	139.19266	2.08E-29	.032	2338.737	1	24	25	1	24	23	SG	75	66	7
36	140.97360	5.53E-30	.032	2338.737	1	25	25	1	24	23	SH	75	66	7
37	148.23945	2.60E-30	.032	2479.710	1	26	27	1	25	25	SF	75	66	7
38	150.45451	1.12E-29	.032	2477.495	1	26	27	1	26	25	SG	75	66	7
39	152.21658	2.96E-30	.032	2477.495	1	27	27	1	26	25	SH	75	66	7
40	159.45767	1.32E-30	.032	2629.712	1	28	29	1	27	27	SF	75	66	7
41	161.69148	5.68E-30	.032	2627.478	1	28	29	1	28	27	SG	75	66	7
42	163.43480	1.49E-30	.032	2627.478	1	29	29	1	28	27	SH	75	66	7
43	170.64931	6.34E-31	.032	2790.913	1	30	31	1	29	29	SF	75	66	7
44	172.90175	2.71E-30	.032	2788.661	1	30	31	1	30	29	SG	75	66	7
45	174.62644	7.11E-31	.032	2788.661	1	31	31	1	30	29	SH	75	66	7
46	181.81251	2.86E-31	.032	2963.287	1	32	33	1	31	31	SF	75	66	7
47	184.08351	1.22E-30	.032	2961.016	1	32	33	1	32	31	SG	75	66	7

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

AF5K15V1 B0, B1, ETC.: REF. 5, O16-O16 SUBMM LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	185.78964	3.19E-31	.032	2961.016	1	33	33	1	32	31	SH	75	66	7
49	192.94544	1.22E-31	.032	3146.806	1	34	35	1	33	33	SF	75	66	7
50	195.23493	5.19E-31	.032	3144.516	1	34	35	1	34	33	SG	75	66	7
51	196.92257	1.35E-31	.032	3144.516	1	35	35	1	34	33	SH	75	66	7
52	204.04625	4.92E-32	.032	3341.439	1	36	37	1	35	35	SF	75	66	7
53	206.35417	2.08E-31	.032	3339.131	1	36	37	1	36	35	SG	75	66	7
54	208.02338	5.42E-32	.032	3339.131	1	37	37	1	36	35	SH	75	66	7
55	215.11309	1.87E-32	.032	3547.154	1	38	39	1	37	37	SF	75	66	7
56	217.43938	7.91E-32	.032	3544.828	1	38	39	1	38	37	SG	75	66	7
57	219.09022	2.05E-32	.032	3544.828	1	39	39	1	38	37	SH	75	66	7
58	226.14411	6.73E-33	.032	3763.918	1	40	41	1	39	39	SF	75	66	7
59	228.46874	2.84E-32	.032	3761.573	1	40	41	1	40	39	SG	75	66	7
60	230.12124	7.35E-33	.032	3761.573	1	41	41	1	40	39	SH	75	66	7
61	237.13745	2.29E-33	.032	3991.695	1	42	43	1	41	41	SF	75	66	7
62	239.50038	9.63E-33	.032	3989.332	1	42	43	1	42	41	SG	75	66	7
63	241.11458	2.49E-33	.032	3989.332	1	43	43	1	42	41	SH	75	66	7
64	248.09127	7.36E-34	.032	4230.446	1	44	45	1	43	43	SF	75	66	7
65	250.47247	3.09E-33	.032	4228.065	1	44	45	1	44	43	SG	75	66	7
66	252.06840	7.98E-34	.032	4228.065	1	45	45	1	44	43	SH	75	66	7
67	259.00371	2.24E-34	.032	4480.134	1	46	47	1	45	45	SF	75	66	7
68	261.40314	9.40E-34	.032	4477.734	1	46	47	1	46	45	SG	75	66	7
69	262.98084	2.42E-34	.032	4477.734	1	47	47	1	46	45	SH	75	66	7
70	269.87291	6.46E-35	.032	4740.715	1	48	49	1	47	47	SF	75	66	7
71	272.29056	2.71E-34	.032	4738.297	1	48	49	1	48	47	SG	75	66	7
72	273.85004	6.96E-35	.032	4738.297	1	49	49	1	48	47	SH	75	66	7
73	280.69701	1.76E-35	.032	5012.147	1	50	51	1	49	49	SF	75	66	7
74	283.13286	7.38E-35	.032	5009.711	1	50	51	1	50	49	SG	75	66	7
75	284.67414	1.90E-35	.032	5009.711	1	51	51	1	50	49	SH	75	66	7
76	291.47417	4.56E-36	.032	5294.366	1	52	53	1	51	51	SF	75	66	7
77	293.92619	1.91E-35	.032	5291.932	1	52	53	1	52	51	SG	75	66	7
78	295.45130	4.89E-36	.032	5291.932	1	53	53	1	52	51	SH	75	66	7
79	302.20252	1.12E-36	.032	5587.383	1	54	55	1	53	53	SF	75	66	7
80	304.67470	4.67E-36	.032	5584.911	1	54	55	1	54	53	SG	75	66	7
81	306.17965	1.20E-36	.032	5584.911	1	55	55	1	54	53	SH	75	66	7

APPENDIX G

RRI Absorption Line Parameters for Molecular Oxygen Isotopes $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$ Whose Line Strengths Exceed 3.7 E-30

See text, page 33 for discussion of the relationship of the file OXYGENEXIST to the eight files listed in Appendix F. The units are the same as in Appendix F.

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

ALL LINES OF O16-O16, O16-O18, AND O18-O18 WITH V = 0 OR 1
AND WHOSE STRENGTHS EXCEED 3.7E-30 INV CM PER MOLECULE PER CM SQ
AT 296K. LINEWIDTHS INTERPOLATED FROM KRUPENIE'S COMPILATION;
B0, B1, B2, ETC., FROM REF. 7 FOR V = 0, FROM REF. 5 FOR V = 1.

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	1.64953	4.62E-30	.032	2460.774	0	41	41	0	40	41	41-	75	66	7
2	1.66655	1.38E-29	.032	2230.425	0	39	39	0	38	39	39-	75	66	7
3	1.68362	3.87E-29	.032	2011.215	0	37	37	0	36	37	37-	75	66	7
4	1.70076	1.03E-28	.032	1803.180	0	35	35	0	34	35	35-	75	66	7
5	1.71796	2.58E-28	.032	1606.353	0	33	33	0	32	33	33-	75	66	7
6	1.73524	6.09E-28	.032	1420.767	0	31	31	0	30	31	31-	75	66	7
7	1.75262	1.36E-27	.032	1246.452	0	29	29	0	28	29	29-	75	66	7
8	1.76431	3.73E-30	.032	1178.121	0	29	29	0	28	29	29-	75	66	7
9	1.77012	2.85E-27	.032	1083.436	0	27	27	0	26	27	27-	75	68	7
10	1.77256	5.33E-30	.032	1099.777	0	28	28	0	27	28	28-	75	66	7
11	1.78084	7.49E-30	.032	1024.107	0	27	27	0	26	27	27-	75	68	7
12	1.78776	5.63E-27	.032	931.745	0	25	25	0	24	25	25-	75	68	7
13	1.78914	1.04E-29	.032	951.113	0	26	26	0	25	26	26-	75	66	7
14	1.79748	1.42E-29	.032	880.799	0	25	25	0	24	25	25-	75	68	7
15	1.79998	5.57E-30	.038	2339.133	1	23	23	1	22	23	23-	75	68	7
16	1.80558	1.05E-26	.038	791.405	0	23	23	0	22	23	23-	75	66	7
17	1.80586	1.91E-29	.035	813.167	0	24	24	0	23	24	24-	75	66	7
18	1.81428	2.54E-29	.038	748.219	0	23	23	0	22	23	23-	75	68	7
19	1.81923	9.67E-30	.035	2211.583	1	21	21	1	20	21	21-	75	68	7
20	1.82275	3.32E-29	.037	685.959	0	22	22	0	21	22	22-	75	66	7
21	1.82363	1.83E-26	.035	662.437	0	21	21	0	20	21	21-	75	68	7
22	1.83127	4.28E-29	.035	626.388	0	21	21	0	20	21	21-	75	66	7
23	1.83877	1.58E-29	.037	2095.301	1	19	19	1	18	19	19-	75	68	7
24	1.83986	5.43E-29	.036	569.509	0	20	20	0	19	20	20-	75	66	7
25	1.84199	3.00E-26	.037	544.863	0	19	19	0	18	19	19-	75	68	7
26	1.84852	6.78E-29	.037	515.324	0	19	19	0	18	19	19-	75	66	7
27	1.85727	8.34E-29	.038	463.835	0	18	18	0	17	18	18-	75	68	7
28	1.85869	2.41E-29	.038	1990.305	1	17	17	1	16	17	17-	75	68	7
29	1.86075	4.60E-26	.038	438.702	0	17	17	0	16	17	17-	75	66	7
30	1.86611	1.01E-28	.038	415.043	0	17	17	0	16	17	17-	75	66	7
31	1.87509	1.20E-28	.038	368.952	0	16	16	0	15	16	16-	75	68	7
32	1.87679	2.74E-26	.045	2.084	0	1	1	0	2	1	1+	75	68	7
33	1.87915	3.43E-29	.038	1896.613	1	15	15	1	14	15	15-	75	66	7
34	1.88008	6.58E-26	.038	343.970	0	15	15	0	14	15	15-	75	66	7
35	1.88420	1.41E-28	.038	325.562	0	15	15	0	14	15	15-	75	66	7
36	1.88985	1.42E-29	.045	1558.465	1	1	1	1	2	1	1+	75	68	7
37	1.89204	5.40E-29	.045	2.633	0	1	1	0	2	1	1+	75	66	7
38	1.89350	1.62E-28	.039	284.875	0	14	14	0	13	14	14-	75	68	7
39	1.90026	8.77E-26	.039	260.683	0	13	13	0	12	13	13-	75	68	7
40	1.90041	4.56E-29	.039	1814.239	1	13	13	1	12	13	13-	75	66	7
41	1.90302	1.83E-28	.039	246.893	0	13	13	0	12	13	13-	75	66	7
42	1.91282	2.03E-28	.040	211.617	0	12	12	0	11	12	12-	75	68	7
43	1.92175	1.08E-25	.041	188.853	0	11	11	0	10	11	11-	75	68	7
44	1.92295	5.61E-29	.041	1743.197	1	11	11	1	10	11	11-	75	66	7

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (A[illegible] FORMAT

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
45	1.92298	2.21E-28	.041	179.048	0	11	11	0	10	11	11-	75	68	7
46	1.93133	1.03E-28	.047	8.025	0	2	2	0	3	2	2+	75	68	7
47	1.93361	2.36E-28	.042	149.187	0	10	10	0	9	10	10-	75	68	7
48	1.94488	2.46E-28	.043	122.036	0	9	9	0	8	9	9-	75	68	7
49	1.94548	1.22E-25	.043	128.492	0	9	9	0	8	9	9-	75	66	7
50	1.94764	6.33E-29	.043	1683.497	1	9	9	1	8	9	9-	75	66	7
51	1.94957	7.55E-26	.044	16.388	0	3	3	0	4	3	3+	75	66	7
52	1.95657	1.48E-28	.044	16.146	0	3	3	0	4	3	3+	75	68	7
53	1.95705	2.50E-28	.044	97.595	0	8	8	0	7	8	8-	75	68	7
54	1.96204	3.92E-29	.044	1572.612	1	3	3	1	4	3	3+	75	66	7
55	1.97052	2.48E-28	.044	75.865	0	7	7	0	6	7	7-	75	68	7
56	1.97351	1.26E-25	.044	79.607	0	7	7	0	6	7	7-	75	66	7
57	1.97549	1.87E-28	.043	26.989	0	4	4	0	5	4	4+	75	68	7
58	1.97649	6.48E-29	.044	1635.147	1	7	7	1	6	7	7-	75	66	7
59	1.98602	2.39E-28	.044	56.845	0	6	6	0	5	6	6-	75	68	7
60	1.98774	1.11E-25	.042	42.224	0	5	5	0	6	5	5+	75	66	7
61	1.99103	2.19E-28	.042	40.550	0	5	5	0	6	5	5+	75	68	7
62	2.00064	5.80E-29	.042	1598.164	1	5	5	1	6	5	5+	75	66	7
63	2.00455	2.44E-28	.041	56.827	0	6	6	0	7	6	6+	75	68	7
64	2.00491	2.21E-28	.044	40.536	0	5	5	0	4	5	5-	75	68	7
65	2.01159	1.13E-25	.044	42.200	0	5	5	0	4	5	5-	75	66	7
66	2.01509	5.84E-29	.044	1598.149	1	5	5	1	4	5	5-	75	66	7
67	2.01589	1.31E-25	.041	79.565	0	7	7	0	8	7	7+	75	66	7
68	2.01677	2.61E-28	.041	75.819	0	7	7	0	8	7	7+	75	68	7
69	2.02811	2.69E-28	.041	97.524	0	8	8	0	9	8	8+	75	68	7
70	2.02949	6.85E-29	.041	1635.094	1	7	7	1	8	7	7+	75	66	7
71	2.03011	1.95E-28	.045	26.934	0	4	4	0	3	4	4-	75	68	7
72	2.03881	2.71E-28	.040	121.942	0	9	9	0	10	9	9+	75	68	7
73	2.03976	1.35E-25	.040	128.398	0	9	9	0	10	9	9+	75	66	7
74	2.04904	2.65E-28	.039	149.072	0	10	10	0	11	10	10+	75	68	7
75	2.05418	7.06E-29	.040	1683.390	1	9	9	1	10	9	9+	75	66	7
76	2.05892	2.54E-28	.039	178.912	0	11	11	0	12	11	11+	75	68	7
77	2.06143	1.25E-25	.039	188.714	0	11	11	0	12	11	11+	75	66	7
78	2.06853	2.38E-28	.039	211.461	0	12	12	0	13	12	12+	75	68	7
79	2.06938	1.61E-28	.047	16.033	0	3	3	0	2	3	3-	75	68	7
80	2.07672	6.55E-29	.039	1743.043	1	11	11	1	12	11	11+	75	66	7
81	2.07792	2.18E-28	.038	246.718	0	13	13	0	14	13	13+	75	68	7
82	2.08181	1.05E-25	.038	260.501	0	13	13	0	14	13	13+	75	66	7
83	2.08432	8.41E-26	.047	16.253	0	3	3	0	2	3	3-	75	66	7
84	2.08715	1.97E-28	.036	284.681	0	14	14	0	15	14	14+	75	68	7
85	2.08728	4.32E-29	.047	1572.486	1	3	3	1	2	3	3-	75	66	7
86	2.09623	1.74E-28	.034	325.350	0	15	15	0	16	15	15+	75	68	7
87	2.09798	5.56E-29	.038	1814.041	1	13	13	1	14	13	13+	75	66	7
88	2.10139	8.23E-26	.034	343.748	0	15	15	0	16	15	15+	75	66	7
89	2.10519	1.52E-28	.035	368.722	0	16	16	0	17	16	16+	75	68	7
90	2.11406	1.30E-28	.036	414.795	0	17	17	0	18	17	17+	75	68	7
91	2.11644	4.37E-29	.034	1896.373	1	15	15	1	16	15	15+	75	66	7
92	2.12042	5.97E-26	.036	438.442	0	17	17	0	18	17	17+	75	66	7
93	2.12285	1.09E-28	.036	463.569	0	18	18	0	19	18	18+	75	68	7
94	2.13158	9.03E-29	.035	515.041	0	19	19	0	20	19	19+	75	68	7

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
95	2.13836	3.19E-29	.036	1990.025	1	17	17	1	18	17	17+	75	66	7
96	2.13907	4.04E-26	.035	544.566	0	19	19	0	20	19	19+	75	66	7
97	2.14024	7.35E-29	.035	569.208	0	20	20	0	21	20	20+	75	68	7
98	2.14886	5.90E-29	.035	626.070	0	21	21	0	22	21	21+	75	68	7
99	2.15239	1.18E-28	.048	7.804	0	2	2	0	1	2	2-	75	68	7
100	2.15744	4.66E-29	.034	685.624	0	22	22	0	23	22	22+	75	68	7
101	2.15746	2.56E-26	.035	662.103	0	21	21	0	22	21	21+	75	66	7
102	2.15790	2.17E-29	.035	2094.982	1	19	19	1	20	19	19+	75	66	7
103	2.16698	3.62E-29	.032	747.867	0	23	23	0	24	23	23+	75	68	7
104	2.17450	2.78E-29	.032	812.798	0	24	24	0	25	24	24+	75	68	7
105	2.17564	1.52E-26	.032	791.034	0	23	23	0	24	23	23+	75	66	7
106	2.17715	1.39E-29	.035	2211.225	1	21	21	1	22	21	21+	75	66	7
107	2.18298	2.10E-29	.032	880.413	0	25	25	0	26	25	25+	75	68	7
108	2.19145	1.56E-29	.032	950.711	0	26	26	0	27	26	26+	75	68	7
109	2.19368	8.49E-27	.032	931.339	0	25	25	0	26	25	25+	75	66	7
110	2.19619	8.29E-30	.032	2338.737	1	23	23	1	24	23	23+	75	66	7
111	2.19989	1.14E-29	.032	1023.688	0	27	27	0	28	27	27+	75	68	7
112	2.20832	8.28E-30	.032	1099.341	0	28	28	0	29	28	28+	75	68	7
113	2.21160	4.45E-27	.032	1082.994	0	27	27	0	28	27	27+	75	66	7
114	2.21506	4.66E-30	.032	2477.495	1	25	25	1	26	25	25+	75	66	7
115	2.21674	5.90E-30	.032	1177.668	0	29	29	0	30	29	29+	75	68	7
116	2.22514	4.15E-30	.032	1258.667	0	30	30	0	31	30	30+	75	68	7
117	2.22943	2.20E-27	.032	1245.975	0	29	29	0	30	29	29+	75	66	7
118	2.24720	1.02E-27	.032	1420.255	0	31	31	0	32	31	31+	75	66	7
119	2.26492	4.48E-28	.032	1605.806	0	33	33	0	34	33	33+	75	66	7
120	2.28260	1.85E-28	.032	1802.598	0	35	35	0	36	35	35+	75	66	7
121	2.30026	7.24E-29	.032	2010.599	0	37	37	0	38	37	37+	75	66	7
122	2.31789	2.67E-29	.032	2229.774	0	39	39	0	40	39	39+	75	66	7
123	2.33551	9.29E-30	.032	2460.088	0	41	41	0	42	41	41+	75	66	7
124	3.96108	1.00E-25	.050	0.000	0	1	1	0	0	1	1-	75	66	7
125	3.96140	1.94E-28	.050	0.363	0	1	1	0	0	1	1-	75	68	7
126	3.97713	5.17E-29	.050	1556.378	1	1	1	1	0	1	1-	75	66	7
127	7.80360	2.91E-28	.050	0.000	0	1	2	0	1	0	8Q	75	68	7
128	9.95599	1.67E-28	.050	0.000	0	2	2	0	1	0	8H	75	68	7
129	11.50856	4.25E-29	.048	4.525	0	2	3	0	1	1	8F	75	68	7
130	12.13118	1.14E-29	.048	1560.355	1	2	3	1	1	1	8F	75	66	7
131	12.29179	2.22E-26	.048	3.961	0	2	3	0	1	1	8F	75	66	7
132	13.40060	4.72E-28	.045	2.633	0	2	3	0	2	1	8Q	75	68	7
133	14.02102	1.25E-28	.045	1558.465	1	2	3	1	2	1	8Q	75	66	7
134	14.16858	2.43E-25	.045	2.084	0	2	3	0	2	1	8Q	75	66	7
135	15.46998	2.05E-28	.045	2.633	0	3	3	0	2	1	8H	75	68	7
136	16.10831	5.38E-29	.045	1558.465	1	3	3	1	2	1	8H	75	66	7
137	16.25289	1.04E-25	.045	2.084	0	3	3	0	2	1	8H	75	66	7
138	16.97828	8.41E-29	.048	9.956	0	3	4	0	2	2	8F	75	68	7
139	18.90961	6.35E-28	.047	8.025	0	3	4	0	3	2	8Q	75	68	7
140	20.93973	2.40E-28	.047	8.025	0	4	4	0	3	2	8H	75	68	7
141	22.43321	1.22E-28	.045	18.103	0	4	5	0	3	3	8F	75	68	7
142	23.57570	3.24E-29	.045	1574.574	1	4	5	1	3	3	8F	75	66	7
143	23.86295	6.28E-26	.045	18.337	0	4	5	0	3	3	8F	75	66	7
144	24.38978	7.75E-28	.044	16.146	0	4	5	0	4	3	8Q	75	68	7

OXYGENEX.ST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
145	25.53774	2.05E-28	.044	1572.612	1	4	5	1	4	3	SG	75	66	7
146	25.81252	3.96E-25	.044	16.388	0	4	5	0	4	3	SG	75	66	7
147	26.39469	2.69E-28	.044	16.146	0	5	5	0	4	3	SH	75	68	7
148	27.55283	7.08E-29	.044	1572.612	1	5	5	1	4	3	SH	75	66	7
149	27.82411	1.37E-25	.044	16.388	0	5	5	0	4	3	SH	75	66	7
150	27.88090	1.53E-28	.044	28.964	0	5	6	0	4	4	SF	75	68	7
151	29.85639	8.87E-28	.043	26.989	0	5	6	0	5	4	SG	75	68	7
152	31.84241	2.92E-28	.043	26.989	0	6	6	0	5	4	SH	75	68	7
153	33.32407	1.78E-28	.043	42.541	0	6	7	0	5	5	SF	75	68	7
154	34.98245	4.71E-29	.043	1600.164	1	6	7	1	5	5	SF	75	66	7
155	35.31609	9.69E-28	.042	40.550	0	6	7	0	6	5	SG	75	68	7
156	35.39530	9.10E-26	.043	44.212	0	6	7	0	5	5	SF	75	66	7
157	36.98309	2.55E-28	.042	1598.164	1	6	7	1	6	5	SG	75	66	7
158	37.28562	3.06E-28	.042	40.550	0	7	7	0	6	5	SH	75	68	7
159	37.38305	4.91E-25	.042	42.224	0	6	7	0	6	5	SG	75	66	7
160	38.76386	1.96E-28	.043	58.831	0	7	8	0	6	6	SF	75	68	7
161	38.95958	8.01E-29	.042	1598.164	1	7	7	1	6	5	SH	75	66	7
162	39.35655	1.54E-25	.042	42.224	0	7	7	0	6	5	SH	75	66	7
163	40.76842	1.02E-27	.041	56.827	0	7	8	0	7	6	SG	75	68	7
164	42.72546	3.13E-28	.041	56.827	0	8	8	0	7	6	SH	75	68	7
165	44.20080	2.07E-28	.042	77.835	0	8	9	0	7	7	SF	75	68	7
166	46.21758	1.04E-27	.041	75.819	0	8	9	0	8	7	SG	75	68	7
167	46.37341	5.40E-29	.042	1637.123	1	8	9	1	7	7	SF	75	66	7
168	46.91156	1.04E-25	.042	81.581	0	8	9	0	7	7	SF	75	66	7
169	48.16245	3.12E-28	.041	75.819	0	9	9	0	8	7	SH	75	68	7
170	48.40290	2.71E-28	.041	1635.094	1	8	9	1	8	7	SG	75	66	7
171	48.92745	5.22E-25	.041	79.565	0	8	9	0	8	7	SG	75	66	7
172	49.63509	2.11E-28	.042	99.552	0	9	10	0	8	8	SF	75	68	7
173	50.35054	8.09E-29	.041	1635.094	1	9	9	1	8	7	SH	75	66	7
174	50.87292	1.56E-25	.041	79.565	0	9	9	0	8	7	SH	75	66	7
175	51.66320	1.03E-27	.041	97.524	0	9	10	0	9	8	SG	75	68	7
176	53.59681	3.04E-28	.041	97.524	0	10	10	0	9	8	SH	75	68	7
177	55.06678	2.08E-28	.041	123.981	0	10	11	0	9	9	SF	75	68	7
178	57.10558	1.00E-27	.040	121.942	0	10	11	0	10	9	SG	75	68	7
179	57.75231	5.37E-29	.041	1685.444	1	10	11	1	9	9	SF	75	66	7
180	58.41563	1.03E-25	.041	130.438	0	10	11	0	9	9	SF	75	66	7
181	59.02856	2.90E-28	.040	121.942	0	11	11	0	10	9	SH	75	68	7
182	59.80650	2.58E-28	.040	1683.390	1	10	11	1	10	9	SG	75	66	7
183	60.45539	4.95E-25	.040	128.398	0	10	11	0	10	9	SG	75	66	7
184	60.49582	2.01E-28	.041	151.121	0	11	12	0	10	10	SF	75	68	7
185	61.72944	7.45E-29	.040	1683.390	1	11	11	1	10	9	SH	75	66	7
186	62.37713	1.43E-25	.040	128.398	0	11	11	0	10	9	SH	75	66	7
187	62.54486	9.49E-28	.039	149.072	0	11	12	0	11	10	SG	75	68	7
188	64.45768	2.72E-28	.039	149.072	0	12	12	0	11	10	SH	75	68	7
189	65.92213	1.89E-28	.041	180.971	0	12	13	0	11	11	SF	75	68	7
190	67.98106	8.82E-28	.039	178.912	0	12	13	0	12	11	SG	75	68	7
191	69.11929	4.80E-29	.041	1745.120	1	12	13	1	11	11	SF	75	66	7
192	69.88407	2.50E-28	.039	178.912	0	13	13	0	12	11	SH	75	68	7
193	69.90770	9.19E-26	.041	190.775	0	12	13	0	11	11	SF	75	66	7
194	71.19601	2.24E-28	.039	1743.043	1	12	13	1	12	11	SG	75	66	7

OXYGENFX.ST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
195	71.34558	1.74E-28	.040	213.530	0	13	14	0	12	12	SF	75	68	7
196	71.46913	4.28E-25	.039	188.714	0	12	13	0	12	11	SG	75	66	7
197	73.09642	6.32E-29	.039	1743.043	1	13	13	1	12	11	SH	75	66	7
198	73.41411	8.03E-28	.039	211.461	0	13	14	0	13	12	SG	75	68	7
199	73.86939	1.21E-25	.039	188.714	0	13	13	0	12	11	SH	75	66	7
200	75.30761	2.25E-28	.039	211.461	0	14	14	0	13	12	SH	75	68	7
201	76.76602	1.57E-28	.038	248.796	0	14	15	0	13	13	SF	75	68	7
202	78.84394	7.18E-28	.038	246.718	0	14	15	0	14	13	SG	75	68	7
203	80.47340	3.92E-29	.038	1816.139	1	14	15	1	13	13	SF	75	66	7
204	80.72815	2.00E-28	.038	246.718	0	15	15	0	14	13	SH	75	68	7
205	81.38685	7.48E-26	.038	262.583	0	14	15	0	13	13	SF	75	66	7
206	82.18328	1.39E-28	.038	286.769	0	15	16	0	14	14	SF	75	68	7
207	82.57138	1.79E-28	.038	1814.041	1	14	15	1	14	13	SG	75	[illegible]	7
208	83.46866	3.41E-25	.038	260.501	0	14	15	0	14	13	SG	75	66	7
209	84.27043	6.30E-28	.036	284.681	0	15	16	0	15	14	SG	75	68	7
210	84.45053	4.97E-29	.038	1814.041	1	15	15	1	14	13	SH	75	66	7
211	85.34874	5.46E-26	.038	260.501	0	15	15	0	14	13	SH	75	66	7
212	86.14551	1.74E-28	.036	284.681	0	16	16	0	15	14	SH	75	68	7
213	87.59720	1.21E-28	.036	327.446	0	16	17	0	15	15	SF	75	68	7
214	89.69343	5.44E-28	.034	325.150	0	16	17	0	16	15	SG	75	68	7
215	91.55954	1.49E-28	.034	325.150	0	17	17	0	16	15	SH	75	68	7
216	91.81322	2.96E-29	.036	1898.492	1	16	17	1	15	15	SF	75	66	7
217	92.85169	5.62E-26	.036	345.850	0	16	17	0	15	15	SF	75	66	7
218	93.00758	1.03E-28	.037	370.827	0	17	18	0	16	16	SF	75	68	7
219	93.93166	1.33E-28	.034	1896.373	1	16	17	1	16	15	SG	75	66	7
220	94.95307	2.52E-25	.034	343.748	0	16	17	0	16	15	SG	75	66	7
221	95.11278	4.61E-28	.035	368.722	0	17	18	0	17	16	SG	75	68	7
222	95.79035	3.65E-29	.034	1896.373	1	17	17	1	16	15	SH	75	66	7
223	96.81382	6.91E-26	.034	343.748	0	17	17	0	16	15	SH	75	66	7
224	96.97004	1.26E-28	.035	368.722	0	18	18	0	17	16	SH	75	68	7
225	98.41425	8.67E-29	.037	416.909	0	18	19	0	17	17	SF	75	68	7
226	100.52832	3.85E-28	.036	414.795	0	18	19	0	18	17	SG	75	68	7
227	102.37684	1.05E-28	.036	414.795	0	19	19	0	18	17	SH	75	68	7
228	103.13716	2.08E-29	.037	1992.164	1	18	19	1	17	17	SF	75	66	7
229	103.81702	7.16E-29	.037	465.692	0	19	20	0	18	18	SF	75	68	7
230	104.30063	3.92E-26	.03[illegible]	440.562	0	18	19	0	17	17	SF	75	66	7
231	105.27552	9.23E-29	.036	1990.025	1	18	19	1	18	17	SG	75	66	7
232	105.93987	3.17E-28	.036	463.569	0	19	20	0	19	18	SG	75	68	7
233	106.42105	1.74E-25	.036	438.442	0	18	19	0	18	17	SG	75	66	7
234	107.11429	2.50E-29	.036	1990.025	1	19	19	1	18	17	SH	75	66	7
235	107.77973	8.56E-29	.036	463.569	0	20	20	0	19	18	SH	75	68	7
236	108.26304	4.72E-26	.036	438.442	0	19	19	0	18	17	SH	75	66	7
237	109.21568	5.82E-29	.036	517.172	0	20	21	0	19	19	SF	75	68	7
238	111.34725	2.56E-28	.035	515.041	0	20	21	0	20	19	SG	75	68	7
239	113.17852	6.90E-29	.035	515.041	0	21	21	0	20	19	SH	75	68	7
240	114.44353	1.36E-29	.036	2097.140	1	20	21	1	19	19	SF	75	66	7
241	114.61004	4.65E-29	.036	571.349	0	21	22	0	20	20	SF	75	68	7
242	115.73199	2.56E-26	.036	546.705	0	20	21	0	19	19	SF	75	66	7
243	116.60142	5.99E-29	.035	2094.982	1	20	21	1	20	19	SG	75	66	7
244	116.75028	2.04E-28	.035	569.208	0	21	22	0	21	20	SG	75	68	7

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
245	117.87106	1.12E-25	.035	544.566	0	20	21	0	20	19	SQ	75	66	7
246	118.42066	1.61E-29	.035	2094.982	1	21	21	1	20	19	SH	75	66	7
247	118.57303	5.47E-29	.035	569.208	0	22	22	0	21	20	SH	75	68	7
248	119.69469	3.02E-26	.035	544.566	0	21	21	0	20	19	SH	75	66	7
249	119.99990	3.66E-29	.035	628.219	0	22	23	0	21	21	SF	75	68	7
250	122.14877	1.60E-28	.035	626.070	0	22	23	0	22	21	SG	75	68	7
251	123.96305	4.28E-29	.035	626.070	0	23	23	0	22	21	SH	75	68	7
252	125.38508	2.84E-29	.036	687.782	0	23	24	0	22	22	SF	75	68	7
253	125.73056	8.35E-30	.035	2213.402	1	22	23	1	21	21	SF	75	66	7
254	127.14400	1.56E-26	.035	664.261	0	22	23	0	21	21	SF	75	66	7
255	127.54252	1.24E-28	.034	685.624	0	23	24	0	23	22	SG	75	68	7
256	127.90771	3.64E-29	.035	2211.225	1	22	23	1	22	21	SQ	75	66	7
257	129.30146	6.79E-26	.035	662.103	0	22	23	0	22	21	SO	75	66	7
258	129.34838	3.30E-29	.034	685.624	0	24	24	0	23	22	SH	75	68	7
259	129.70769	9.73E-30	.035	2211.225	1	23	23	1	22	21	SH	75	66	7
260	130.76535	2.17E-29	.035	750.033	0	24	25	0	23	23	SF	75	68	7
261	131.10704	1.81E-26	.035	662.103	0	23	23	0	22	21	SH	75	66	7
262	132.93134	9.41E-29	.032	747.867	0	24	25	0	24	23	SG	75	68	7
263	134.72882	2.50E-29	.032	747.867	0	25	25	0	24	23	SH	75	68	7
264	136.14053	1.63E-29	.034	814.972	0	25	26	0	24	24	SF	75	68	7
265	136.99647	4.80E-30	.035	2340.933	1	24	25	1	23	23	SF	75	66	7
266	138.31503	7.06E-29	.032	812.798	0	25	26	0	25	24	SG	75	68	7
267	138.53489	8.90E-27	.035	793.210	0	24	25	0	23	23	SF	75	66	7
268	139.19266	2.08E-29	.032	2338.737	1	24	25	1	24	23	SG	75	66	7
269	140.10417	1.87E-29	.032	812.798	0	26	26	0	25	24	SH	75	68	7
270	140.71053	3.86E-26	.032	791.034	0	24	25	0	24	23	SG	75	66	7
271	140.97360	5.53E-30	.032	2338.737	1	25	25	1	24	23	SH	75	66	7
272	141.51041	1.21E-29	.032	882.596	0	26	27	0	25	25	SF	75	68	7
273	142.49829	1.02E-26	.032	791.034	0	25	25	0	24	23	SH	75	66	7
274	143.69339	5.22E-29	.032	880.413	0	26	27	0	26	25	SG	75	68	7
275	145.47423	1.38E-29	.032	880.413	0	27	27	0	26	25	SH	75	68	7
276	146.87478	8.85E-30	.032	952.902	0	27	28	0	26	26	SF	75	68	7
277	149.06623	3.81E-29	.032	950.711	0	27	28	0	27	26	SG	75	68	7
278	149.90285	4.78E-27	.032	933.533	0	26	27	0	25	25	SF	75	66	7
279	150.45451	1.12E-29	.032	2477.[illegible]95	1	26	27	1	26	25	SG	75	66	7
280	150.83879	1.01E-29	.032	950.711	0	28	28	0	27	26	SH	75	68	7
281	152.09653	2.06E-26	.032	931.339	0	26	27	0	26	25	SG	75	66	7
282	152.23345	6.37E-30	.032	1025.887	0	28	29	0	27	27	SF	75	68	7
283	153.86664	5.44E-27	.032	931.339	0	27	27	0	26	25	SH	75	66	7
284	154.43335	2.74E-29	.032	1023.688	0	28	29	0	28	27	SG	75	68	7
285	156.19765	7.21E-30	.032	1023.688	0	29	29	0	28	27	SH	75	68	7
286	157.58621	4.52E-30	.032	1101.549	0	29	30	0	28	28	SF	75	68	7
287	159.79453	1.94E-29	.032	1099.341	0	29	30	0	29	28	SG	75	68	7
288	161.24605	2.41E-27	.032	1085.206	0	28	29	0	27	27	SF	75	66	7
289	161.55061	5.10E-30	.032	1099.341	0	30	30	0	29	28	SH	75	68	7
290	161.69148	5.68E-30	.032	2627.478	1	28	29	1	28	27	SG	75	66	7
291	163.45765	1.03E-26	.032	1082.994	0	28	29	0	28	27	SG	75	66	7
292	165.14960	1.35E-29	.032	1177.668	0	30	31	0	30	29	SG	75	68	7
293	165.21027	2.72E-27	.032	1082.994	0	29	29	0	28	27	SH	75	66	7
294	170.49833	9.33E-30	.032	1258.667	0	31	32	0	31	30	SG	75	68	7

OXYGENFXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCRL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
295	172.56267	1.15E-27	.032	1248.204	0	30	31	0	29	29	SF	75	66	7
296	174.79210	4.89E-27	.032	1245.975	0	30	31	0	30	29	SG	75	66	7
297	175.84053	6.34E-30	.032	1342.332	0	32	33	0	32	31	SG	75	66	7
298	176.52734	1.28E-27	.032	1245.975	0	31	31	0	30	29	SH	75	66	7
299	181.17599	4.25E-30	.032	1428.663	0	33	34	0	33	32	SG	75	66	7
300	183.85086	5.13E-28	.032	1422.502	0	32	33	0	31	31	SF	75	66	7
301	186.09807	2.18E-27	.032	1420.255	0	32	33	0	32	31	SG	75	66	7
302	187.81602	5.71E-28	.032	1420.255	0	33	33	0	32	31	SH	75	66	7
303	195.10879	2.17E-28	.032	1608.071	0	34	35	0	33	33	SF	75	66	7
304	197.37371	9.19E-28	.032	1605.806	0	34	35	0	34	33	SG	75	66	7
305	199.07447	2.40E-28	.032	1605.806	0	35	35	0	34	33	SH	75	66	7
306	206.33461	8.63E-29	.032	1804.881	0	36	37	0	35	35	SF	75	66	7
307	208.61722	3.65E-28	.032	1802.598	0	36	37	0	36	35	SG	75	66	7
308	210.30084	9.50E-29	.032	1802.598	0	37	37	0	36	35	SH	75	66	7
309	217.52647	3.25E-29	.032	2012.899	0	38	39	0	37	37	SF	75	66	7
310	219.82673	1.37E-28	.032	2010.599	0	38	39	0	38	37	SG	75	66	7
311	221.49328	3.56E-29	.032	2010.599	0	39	39	0	38	37	SH	75	66	7
312	228.68253	1.15E-29	.032	2232.092	0	40	41	0	39	39	SF	75	66	7
313	231.00042	4.86E-29	.032	2229.774	0	40	41	0	40	39	SG	75	66	7
314	232.64995	1.26E-29	.032	2229.774	0	41	41	0	40	39	SH	75	66	7
315	239.80093	3.88E-30	.032	2462.424	0	42	43	0	41	41	SF	75	66	7
316	242.13644	1.63E-29	.032	2460.088	0	42	43	0	42	41	SG	75	66	7
317	243.76899	4.21E-30	.032	2460.088	0	43	43	0	42	41	SH	75	66	7
318	253.23294	5.17E-30	.032	2701.504	0	44	45	0	44	43	SG	75	66	7

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